

Biasing reward-based decision-making in obesity

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*„The only way to get rid of temptation is to  
yield to it.“*

*-Oscar Wilde*

## **1. Introduction**

### **1.1 Obesity as a global epidemic**

Worldwide obesity rates have increased dramatically in the last decades resulting in a so-called “obesity epidemic” (World Health Organization (WHO) 2000). In Germany almost one out of four adults is obese, i.e. he exhibits a Body-Mass-Index (BMI) equal to or higher than  $30 \text{ kg/m}^2$  (Robert-Koch-Institut 2014; NCD Risk Factor Collaboration 2016). Obesity is associated with a variety of diseases, most importantly endocrinological diseases, especially Diabetes Mellitus type 2, and cardiovascular diseases, like arterial hypertension and coronary heart disease, but also an increased prevalence of certain types of cancer (Wormser et al. 2011; Prospective Studies Collaboration 2009) and psychiatric disorders (Mather et al. 2009; Simon et al. 2006). Hence, the disease burden is immense.

In addition, the disease burden is accompanied by huge direct and indirect health costs emerging from the treatment of diseases secondary to obesity. These amount to billions in Germany alone (Lehnert et al. 2015) making obesity a problem of utmost significance for policy makers and researchers.

### **1.2 Etiology of the obesity epidemic**

Generally, in order for obesity to occur, energy intake must exceed energy expenditure, at least for a certain period of time. During this time period, the surplus of energy causes weight gain. However, both energy expenditure and energy intake are controlled by the complex interaction (see e.g. Pi-Sunyer 2002) of genetic (Rahilly et al. 2006; Choquet & Meyre 2011; Alfredo Martínez et al. 2007), metabolic, environmental (Hill & Peters 1998) and behavioral factors (see e.g. French et al. 2012; Dietrich et al. 2014; Horstmann et al. 2015). Adding another layer of complexity to these interactions, energy intake is, on the behavioral level, driven by two, possibly overlapping, motivational states (cf. e.g. Begg & Woods 2013; Lowe & Butryn 2007). ‘Hunger’ on the one hand describes the homeostatic drive to ingest food in order to match the energy demands of the organism, and ‘appetite’ on the other

characterizes the hedonic drive to eat beyond physiological need. Due to its complexity and despite a rapidly growing body of research, the etiology of obesity remains far from being understood.

What is apparent, however, is that obesity rates have increased abruptly and markedly in only about three decades.<sup>1</sup>

How can this be explained? The fact that from an evolutionary perspective three decades are a very short time interval suggests that a change in environment rather than in genetic make-up explains the increase in obesity rates. And indeed, the so-called obesity epidemic has developed over a time interval during which the food environment changed dramatically (cf. Jeffery & Utter 2003): In the United States for instance, the number of places to buy ready-to-eat food has doubled and people markedly increased their spending on convenience food, which are often highly palatable but high caloric and unhealthy. The impact of the food environment on overweight and obesity can even be tracked back to the community level where the number of convenience stores in a neighborhood predicts the BMI of its population (Leung et al. 2011).

But what exactly is the mechanism by which a change in (food) environment promotes weight gain? Is it possible that certain genetic and cognitive predispositions have been present throughout parts of the general population for a longer time period making them obesity-prone only now, that the (food) environment has changed to such an extent? If this holds true, several questions occur: what are genetic, cognitive and behavioral characteristics that distinguish obese from lean subjects and how do they promote weight gain in interplay with the environment? And, in addition, do these characteristics predict aberrant behavior in decision-making domains other than food-related decisions?

Aim of this thesis is to help clarify these relationships by adding new evidence to the existing results of research on cognitive and behavioral aberrations in obesity and thereby to contribute to our understanding of the etiology of obesity.

### **1.3 The cognitive component – impulsivity as a potential risk factor for the development of obesity**

Throughout the last decades research has accumulated describing a broad variety of cognitive and behavioral aberrations in people with obesity. Some researchers argue that they are specific enough to form a unique “Obese Cognitive Profile” (Jansen et al. 2015). In claiming so, they rely on research showing impairments in certain

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<sup>1</sup> As data from the United states show, the most pronounced increase in obesity rates occurred between 1980 and 2010 (Selvin et al. 2014)

domains of executive functioning (Fitzpatrick et al. 2013) and in learning tasks (Coppin et al. 2014; Horstmann et al. 2015). Most importantly however, obesity has been shown to be strongly related to impulsivity (Mobbs et al. 2010; Nederkoorn et al. 2006; Kamijo et al. 2012; Batterink et al. 2010; Pignatti et al. 2006; Horstmann et al. 2011).

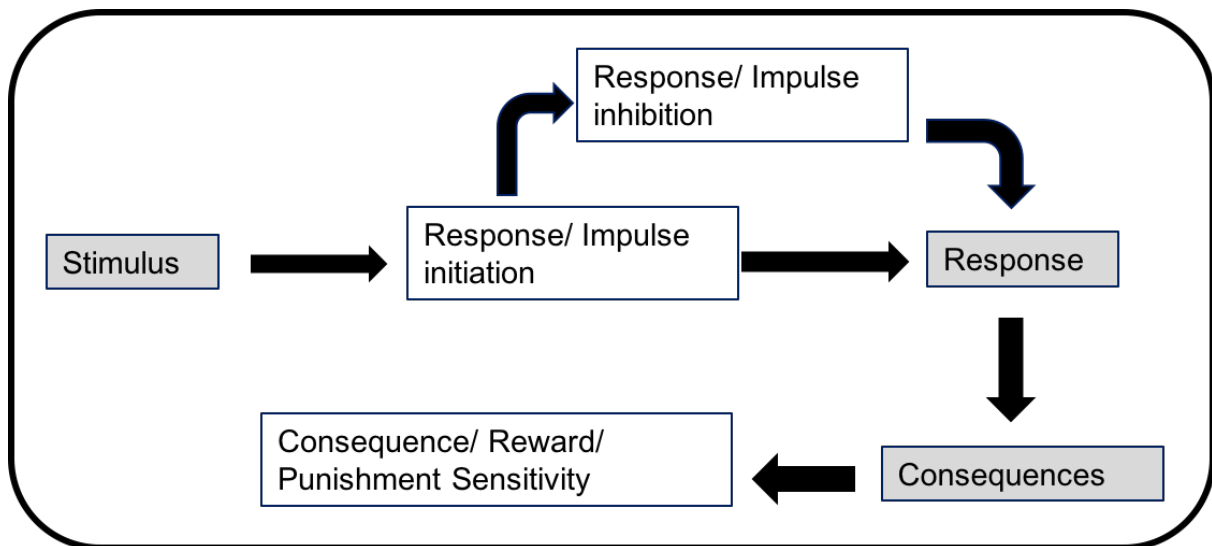
## **1.4 Impulsivity**

Impulsivity refers to a wide range of behaviors that are “poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation” (Daruna & Barnes 1993). The more impulsive a person, the higher the likelihood that his long-term plans and goals are disrupted by emerging impulses. Impulsive behavior appears to be, at least to a certain degree, a core feature of normal behavior (Deyoung 2011). As such, personality psychologists have described it as a stable personality trait with a normal distribution in the general population. (Evenden 1999b; Deyoung 2011; Kirby 2009; Eysenck & Eysenck 1977).

If impulsive behavior reaches a certain level, however, it is considered pathological. Consequently, impulsivity is considered a core feature in many psychiatric disorders, like personality disorders, ADHD and addiction (Evenden 1999a). Thus, because impulsivity entails such a variety of behaviors, reaching from a non-pathological personality trait to the core feature of psychiatric disorders, it remains highly debated if it mirrors a unitary construct or is made up out of several independent factors (Evenden 1999b).

The broad spectrum of impulsive behaviors is mirrored in a high number of different measurements. Impulsivity can be measured by self-report questionnaires, like the Barrat Impulsiveness Scale (Patton et al. 1995) and the U-P-P-S impulsive behavior scale (Whiteside & Lynam 2001) as well as by psychometric tests like the Go/No-Go and the stop-signal task, measuring in the main motor impulsivity (Logan & Cowan 1984).

Yet another aspect of impulsive behavior is the inability to resist immediate gratification and wait for a larger, often more enduring reward. This behavior, called the inability to delay gratification or future discounting, can be measured by a so-called delay discounting (DD) task, which was applied for the present thesis and will be described in more detail later (see 1.5; for an account on how different aspects of impulsivity interact to affect behavior see Figure 1).



**Figure 1:** Dougherty and colleagues (Dougherty et al. 2009) proposed an appealing model of how different aspects of impulsivity (white boxes) might interact to explain impulsive behavior. They propose that impulsive behavior occurs when the following happens: Firstly, a given stimulus induces the initiation of an impulse. Secondly, impulse inhibition failure leads to the manifestation of the impulse/response. Thirdly, insufficient Consequence or Punishment Sensitivity (Carver & White 1994) leads to the continuation of impulsive behavior despite its detrimental consequences.

### 1.4.1 Impulsivity and obesity – current knowledge

There is, by now, a strong unanimity that obesity is linked to certain types of impulsive behaviors. Behavioral measures have consistently been shown to exhibit a strong relationship to obesity, overweight or weight gain from an early age on (Puder & Munsch 2010; Thamotharan et al. 2013; Graziano et al. 2010; Fields et al. 2013; Berg et al. 2011; Lawyer et al. 2015; Weller et al. 2008; Nederkoorn et al. 2006). This applied mostly for measurements which tested impulsivity in a food-context. Tasks which tested for domain-unspecific impulsivity on the other hand, e.g. by using secondary reinforcers such as money, did not always reveal a higher tendency to act impulsively in obese people (cf. e.g. Houben et al. 2014; Thamotharan et al. 2013).

The same applies to the research results trying to relate self-report measurements of impulsivity to obesity (cf. Thamotharan et al. 2013; Rydén et al. 2003). While certain widely used self-report measures, especially the Barratt impulsiveness scale, did not prove to be significantly correlated to obesity at all (see e.g. Dietrich et al. 2014; Nederkoorn et al. 2006), certain dimensions of other self-report measurements could significantly be linked to obesity. Among these are subscales of the U-P-P-S impulsiveness questionnaires, namely ‘Urgency’ (Whiteside & Lynam 2001), describing the presence of strong impulses under negative affect, and ‘Lack of Perseverance’ describing difficulties in focusing on a difficult or boring task (Mobbs et al. 2010).

### **1.4.2 Outlook: impulsivity and eating behavior in obesity**

Eating behavior is typically measured by self-report questionnaires of which the Three-Factor Eating questionnaire (Stunkard & Messick 1985; German: Fragebogen zum Essverhalten (FEV); Pudel & Westenhöfer 1989) plays a paramount role. One of its factors, called ‘disinhibition’ or ‘opportunistic eating’, has been shown to be significantly and strongly related to weight gain and BMI (Bryant et al. 2008; Hays & Roberts 2008; Hays et al. 2002; French et al. 2012). ‘Opportunistic eating’ describes the tendency to lose control over one’s eating behavior, when tempted by environmental cues, or when emotionally moved and under stress. Interestingly, the ‘opportunistic eating’ scale entails a set of personality characteristics that reaches beyond eating behavior, e.g. a generally increased susceptibility of decision-making towards external cues as well as towards stress and unhealthy behaviors like smoking (cf. Bryant et al. 2008). Thus, it apparently overlaps with certain impulsive decision-making patterns. Hence, it remains likely that ‘opportunistic eating’ scores are related to impulsive decision-making outside the food context.

### **1.5 Delay discounting**

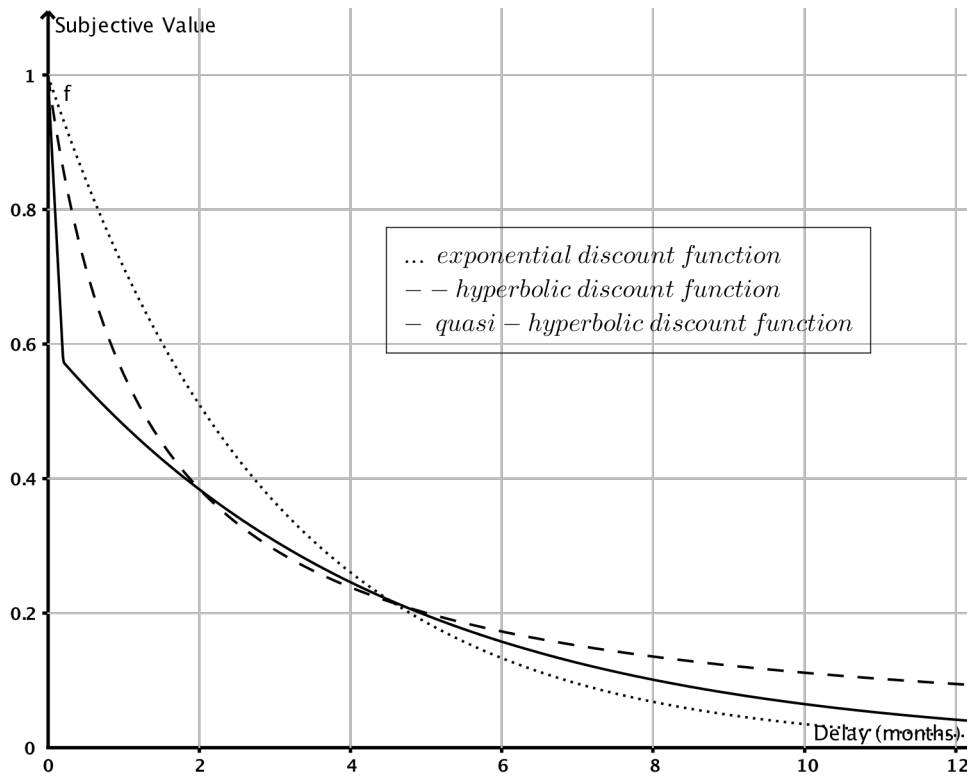
The inability to delay immediate gratification in order to receive a larger reward at a later time point is considered a marker of behavioral impulsivity. In contrast, deciding less impulsive in the presence of immediate rewards has been linked to a diverse set of positive outcomes. In the famous ‘Stanford marshmallow experiment’, conducted by Walter Mischel in the 1960s, preschoolers were seated alone in a laboratory room and presented with a single marshmallow. They were advised that they could eat the marshmallow immediately, but would be given a second if they could resist the temptation of eating the first for fifteen minutes (Mischel et al. 1972). Children who waited for the second marshmallow, i.e. were able to delay immediate gratification, showed markedly better performance on high school admission tests, exhibited higher self-esteem, less aggressive and problematic behaviors, and a lower incidence of drug abuse decades later (see Casey et al. 2011; Mischel et al. 2011).

The ability to delay gratification develops throughout childhood and adolescence (for an early account see: Ainslie 1975) and remains important across multiple domains of decision-making (cf. e.g. Gubler & Pierce 2014). In adulthood it can, among other measures, be tested by a delay discounting task. Delay discounting is a widely used measurement of inter-temporal decision-making, a certain form of reward-based decision-making characterized by the presence of a temporal component. Usually the rewards applied in delay discounting tasks are secondary reinforcers like money, even though accounts of delay discounting with primary reinforcers exist. Typically,



participants of a DD task are presented with a number of combinations of smaller sooner (SS) rewards and larger later (LL) rewards and are advised to choose the combination of reward and delay they prefer.

Different psychometric functions have been proposed to model a participant's choices. They describe the discounting of delayed rewards as a decrease in subjective value of the delayed choice option over time (see Figure 2). While it can be assumed for immediate rewards that the objective value of the reward equals the subjective value, the subjective value of the delayed choice option decreases as a function of time. The form of the function has been described as exponential (Samuelson 1937), hyperbolic (Mazur 1987) or quasi-hyperbolic (Laibson 1997).



**Figure 2:** Different discount functions used to model subjects' decisions in a delay discounting task. The quasi-hyperbolic discount function entails an additional parameter, the so-called present bias  $\beta$ , which is a negative premium on all delayed rewards and allows a sharp distinction between immediate and delayed rewards.

While the exponential discount function is no longer frequently used due to its poor fit, the hyperbolic function remains most commonly used. It produces only one parameter, the discount rate  $k$ , and takes the following form:

$$SV = \frac{1}{1 + k\tau}$$

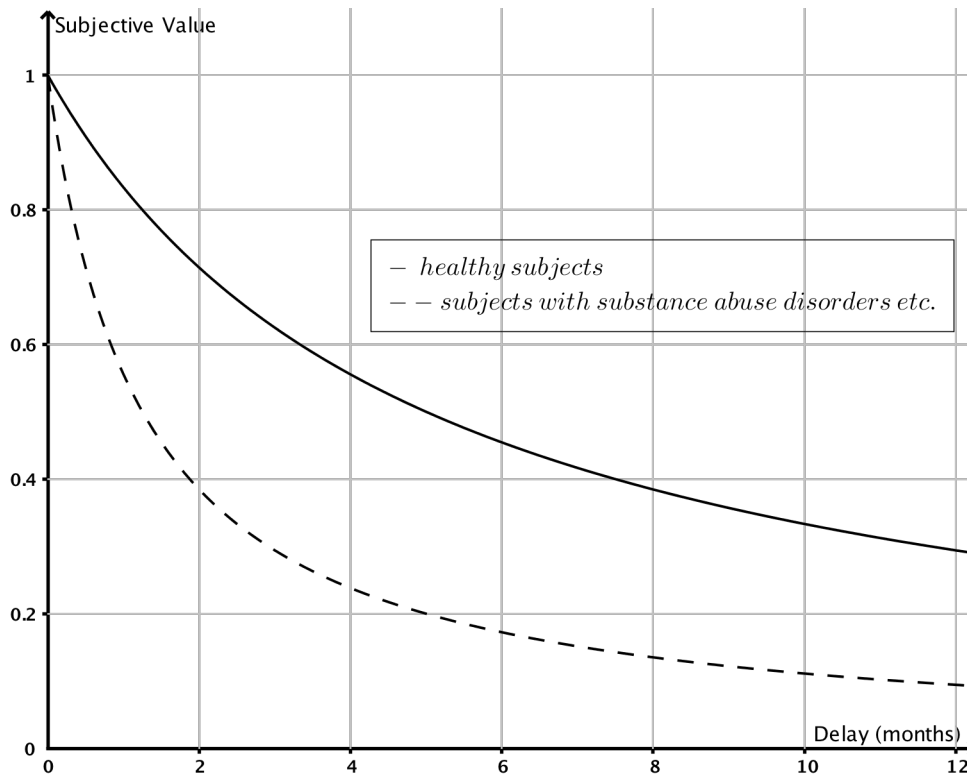
with SV denoting the subjective value of the LL amount as a fraction of the value of the SS amount,  $k$  denoting the discount rate and  $\tau$  denoting the delay; whereas the quasi-hyperbolic discount function entails an additional

parameter, the so-called present bias, a fixed negative premium on the subjective value of each delayed amount allowing a sharp distinction between immediate and delayed rewards. It takes the following form:

$$SV = \beta \delta^\tau$$

with  $\beta$  denoting the present bias and  $\delta$  the discount rate.

Discount rates are stable over time and replicable (Kirby 2009) and have been experimentally linked to a variety of disorders, with affected subjects deciding for more future discounting, i.e. exhibiting less ability to delay gratification, than their healthy counterparts. This applied especially for subjects with substance abuse disorders (alcohol: Bjork et al. 2004; Finn & Hall 2004; methamphetamine: Monterosso et al. 2007; cocaine: Camchong et al. 2011; Kirby & Petry 2003; opioids: Kirby & Petry 2003; Kirby et al. 1999) and pathological gambling (Alessi & Petry 2003; Dixon et al. 2003), but also for those with compulsive behavior like attention-hyperactivity disorders (Luman et al. 2010, see Figure 3).



**Figure 3:** Exemplifying depiction of the loss of subjective value of the delayed choice option as a function of the increase of its delay in a hyperbolic discount function. The solid line depicts a healthy subjects delay discounting task performance, the dashed line in contrast shows the performance of subjects exhibiting substance abuse disorders, pathological gambling and attention-hyperactivity disorders. The latter group shows a markedly faster decrease of subjective value over time. Aim of this thesis is to clarify, if this applies to obese subjects as well (see 1.6.1).

### **1.5.1 Neurological correlates of delay discounting**

Several brain studies aimed at identifying brain regions involved in the computation of the subjective value of a reward. They determined a core domain-general network representing the subjective value of a given choice option in the context of intertemporal choice, consisting of the ventral striatum (VS), the ventromedial orbitofrontal cortex (OFC), also referred to as ventromedial prefrontal cortex (vmPFC), and the posterior cingulate cortex (PCC) (Kable & Glimcher 2007; Kable & Glimcher 2010; Peters & Büchel 2011). Further, the anterior cingulate cortex (ACC) seems to play a crucial role in integrating changes in the decision-making context by receiving input from the PCC, hippocampus and amygdala (Peters & Büchel 2010). Especially the basolateral nucleus of the amygdala might be particularly important, as recent research suggests it might play a central role in integrating reward value, its history and cost parameters (Peters & Büchel 2010a; Wassum & Izquierdo 2015).

Importantly, recent research reported aberrations of components of this domain-general valuation system in obesity (Stoeckel et al. 2008; Horstmann et al. 2011; Mueller et al. 2011; Nummenmaa et al. 2012; García-García et al. 2014). Hence, altered computation of subjective values, e.g. an overvaluation of immediate rewards, is likely to influence decision-making patterns of obese subjects in a DD task, independent of the type of reinforcer (primary like food vs. secondary like money).

In addition, an altered computation would be in accordance with research proving abnormalities in dopaminergic transmission in human and rodent obesity (Cone et al. 2013; Narayanaswami et al. 2012; Sharma & Fulton 2013; Horstmann et al. 2015). The dopaminergic system plays an important role in multiple forms of reward-based decision-making (e.g. Treadway et al. 2012) and in motivating behavior (e.g. Kobayashi & Schultz 2014; Hoebel et al. 2007) and its midbrain neurons project into parts of the valuation network, most importantly, the VS and the OFC.

### **1.6 Delay discounting and obesity**

In accordance with the abnormalities obese subjects exhibit in the value computation network, abnormalities in inter-temporal decision-making have been shown in the context of dietary choices. Everyday dietary choices are often essentially of an inter-temporal nature: choosing between highly-palatable, high-caloric and easily accessible food (e.g. convenience food) and more healthy options (e.g. homemade, not processed food) which in the long-term lead to weight maintenance or weight loss. Subjects with obesity often tend to decide impulsively, i.e.

choosing palatable food thereby neglecting their long-term dietary goals (see e.g. Batterink et al. 2010; Houben et al. 2014; Jasinska et al. 2012).

These decision-making patterns are not restricted to the food context. Recent research reported that obese subjects might exhibit more impulsive decision-making in other contexts as well. For example, obese subjects had more difficulties inhibiting prepotent responses in experimental settings free of food cues (Nederkoorn et al. 2006; Batterink et al. 2010; Kamiyo et al. 2012) and decided more often for immediate rewards at the expense of higher future losses in a card game task called Iowa Gambling task (Pignatti et al. 2006; Brogan et al. 2010; Horstmann et al. 2011).

Regarding performance in a delay discounting task, the current scientific evidence, however, yielded no clear results. At the time the study was implemented, research had found no differences in delay discounting task performance between lean and obese subjects (Nederkoorn et al. 2006), differences accounted for by socioeconomic status, which is known to heavily influence delay discounting task performance (Davis et al. 2010), or differences present only between lean and obese women but not men (Weller et al. 2008).

### **1.6.1 First aim of the present thesis: establishing a general difference in delay discounting task performance between lean and obese**

Thus, the first aim of the present study was to clarify the relationship between delay discounting task performance and obesity. Discovering a domain-general difference between lean and obese subjects would have serious implications given that low levels of impulsivity in intertemporal choice have been linked to educational success, better health and many other positive outcomes (Casey et al. 2011; Mischel et al. 2011, see 1.5)

In order to produce reliable results the groups of participants, divided in weight status and gender subgroups, were thoroughly controlled for variables known to influence performance in intertemporal choice tasks, namely age, educational level, household income (Green et al. 1996) general intelligence (Shamosh & Gray 2008), sensitivity to reward (de Wit et al. 2007), and subjective time perception (Zauberman et al. 2009; Han & Takahashi 2012; Cooper et al. 2013), before testing their inter-temporal choice preferences experimentally.

## 1.7 General stability of decision-making preferences

An altered computation of subjective reward value resulting in stronger future discounting (see 1.5.1) might not be the only aspect of impulsive inter-temporal decision-making. In contrast, I argue, that the degree of stability of decision-making preferences deserves further acknowledgement. Effective and beneficial decision-making requires a certain robustness in decision-making preferences. Deciding in discordance with one's individual long-term goals might constitute an additional aspect of impulsive decision-making.

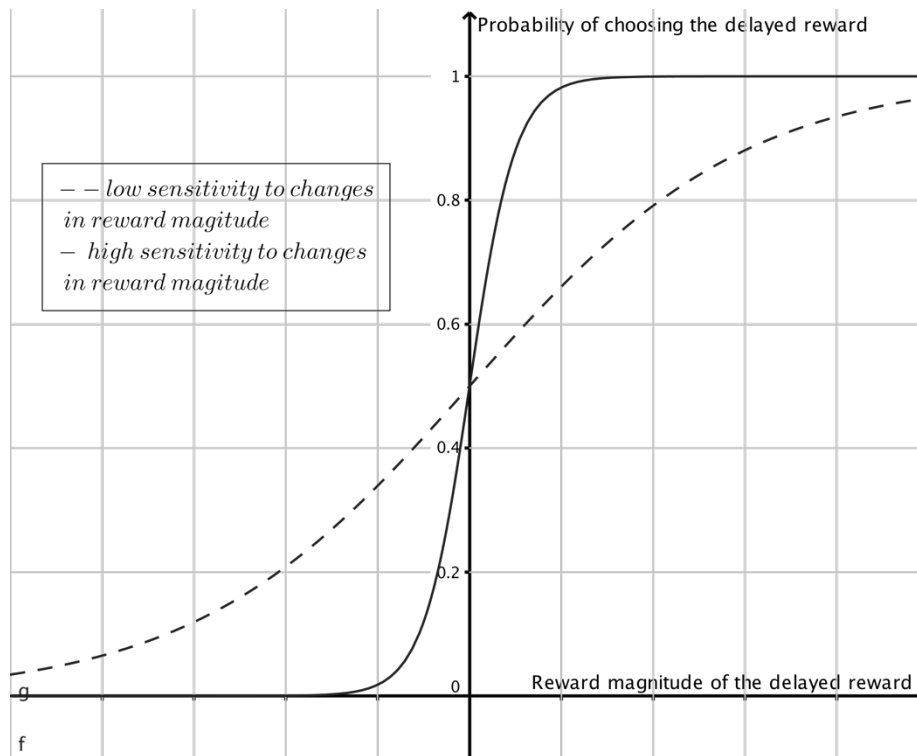
The robustness of inter-temporal decision-making preferences can roughly be divided into a general stability and a stability towards external biasing cues (for the latter see 1.7.1). I argue that the general stability entails the following domains: First, the temporal stability (does the degree of future discounting a subject exhibits change over time?), which can be measured by correlating discount rates assessed repeatedly at different time points<sup>2</sup>; Second, behavioral sensitivity towards changes in reward magnitude, also termed stochasticity of choice (How clear-cut are the decision-making preferences in the light of changing reward magnitudes? See Luo et al. 2012). This sensitivity can be described by the slope of the logistic function describing the probability of a participant choosing the larger later reward (vs. the sooner smaller reward) as a function of the change of its magnitude. It takes the following form:

$$p(LL) = \frac{1}{1 + e^{-\frac{SV(LL) - SV(SS)}{s}}}$$

with  $SV(LL)$  and  $SV(SS)$  describing the subjective value of the delayed and the immediate choice option and parameter  $s$  describing the stochasticity of choices. The steeper the function, the more sensitive a subject towards changes in reward magnitude and the less stochastic his decisions (see Figure 4). Importantly, it could be shown that a high sensitivity towards changes in reward magnitude is accompanied by more efficient decision-making (Luo et al. 2012).

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<sup>2</sup> In general, discount rates have been shown to be relatively stable over time (Kirby 2009, and see chapter 1.5).



**Figure 4:** This softmax/logistic function describes the probability of a participant choosing the delayed choice option in a given trial as a function of the increase of its magnitude. The less stochastic the choices, the steeper the function and the higher the sensitivity towards changes in reward magnitude.

In sum, I hypothesize that temporal stability and behavioral sensitivity towards changes in reward magnitude are the basis for efficient decision-making that produces results in line with subjective goals, being in turn crucial but not restricted to the dietary context. However, to my knowledge no study has ever addressed, if the temporal stability and the sensitivity towards changes in reward magnitude, in other words the general stability of decision-making preferences, is altered in groups exhibiting abnormalities in inter-temporal choice, including obese subjects.

### 1.7.1 Stability towards external cues / Priming

Alongside a general stability of decision-making preferences, the stability of preferences towards biasing external cues is of particular interest, when it comes to understanding the etiology of obesity. Our environment is rich in cues aiming at biasing our behavior. Tempting TV advertisements confront us with new shiny cars challenging a newly set-up savings agreement, the bakery displays all sorts of cake causing our diet plan to totter. Priming research poses the question if and how these cues might affect our behavior, and if even seemingly unrelated cues might do so. One possible mechanism by which this might occur is called ‘automatic goal activation’ (Bargh 1990). It proposes that the presentation with a certain cue can influence the response to a subsequent stimulus,

even if the cue is incidental to the response and only subconsciously perceived (Chartrand & Bargh 1996; Tulving & Schacter 1990). Assuming that the mental representations of goals resemble the mental representations of social constructs and stereotypes, Bargh proposed that the former can be activated by incidental cues, just like it has been shown for the latter (Bargh 1990). The induced ‘automatic’ activation of a particular goal representation changes the perception and attitudes towards the subsequent stimulus and consequently alters the response to it.

Priming with incidental cues has been shown to be effective in different settings (see e.g. Guitart-Masip et al. 2010; Strahan et al. 2002; Bijleveld et al. 2012), including inter-temporal decision-making and delay discounting (Van den Bergh et al. 2008; Zauberman et al. 2009; Murawski et al. 2012; Luo et al. 2014). In the context of delay discounting, most studies showed a pronounced priming effect of rewarding cues towards stronger future discounting.<sup>3</sup>

One study, in contrast, showed a priming effect towards less future discounting by presenting participants with fearful, non-rewarding, faces<sup>4</sup> (Luo et al. 2014). The authors attributed the priming effect to the occurrence of a so-called ‘inhibitory spillover’ (Berkman et al. 2009). Berkman and colleagues argue that intended inhibition in one domain (e.g. affective inhibition or motor inhibition) might lead to unintended inhibition in other domains. This, Luo and colleagues proposed, might have occurred as well, when decisions were primed by fearful faces. An incidental cue perceived as negative might have induced affective inhibition, thereby suppressing behavior aiming at seeking immediate reward (Luo et al. 2014).

### **1.7.2 Priming and obesity**

Establishing differences in the stability of general (see 1.6) or external stability of intertemporal decision-making preferences between lean and obese would enhance our understanding of the cognitive basis of impulsivity. It might help explain, why obese paradoxically tend to make adverse dietary decision despite having strong dietary goals to the contrary. They might simply lack the stability of decision-making preferences necessary to stick to their long-term goals.

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<sup>3</sup> I do consider Episodic Future Thinking to be a form of framing rather than priming (cf. Tversky & Kahneman 1981, 1986; Read et al. 2013). Examining differential effects of framing on reward-based decision-making in obese subjects is not subject of this thesis.

<sup>4</sup> presenting them with happy, i.e. rewarding faces instead had induced stronger future discounting (Luo et al. 2014)

To date an apparent lack of research investigating priming of decision-making in obese subjects can be noted. This is even more surprising given that obese seem to perceive and react differently to the presence of rewarding, especially food-related cues (Cornier et al. 2010; Roefs & Jansen 2002; Czyzewska & Graham 2008). An exception to this apparent lack is research on the induction of desire to eat by food-related cues (see e.g. Kemps et al. 2014) and one study that primed overweight participants with health and diet cues into buying less unhealthy food in a supermarket (Papies et al. 2014).

## **1.8 Aim of this thesis**

The aim of the present thesis is to clarify the relationship between obesity and inter-temporal impulsive decision-making, and to add new aspects to the existing knowledge. It does so by addressing a number of open questions:

1. Is there a general difference in inter-temporal impulsive decision-making between lean and obese subjects, which is independent of gender and other confounding variables (see 1.6.1)? If that holds true, it has important implications. It suggests that obesity is characterized by a reliance on immediate gratification that is not restricted to the food context but domain-general in nature. Thus, it would yield that obesity should neither be considered solely a medical condition, nor should its treatment be based on dietary aspects alone. Instead, it should entail therapeutic options aiming at enhancing cognitive control mechanisms.
2. Is there a general difference in the degree of stability of decision-making preferences between lean and obese subjects? Given that stable decision-making preferences seem to be important for efficient decision-making, an overall difference of stability of decision-making patterns could be detrimental in everyday decisions which require fast and efficient choice taking.
3. Is there an increased susceptibility of decision-making towards incidental rewarding cues in obese subjects? If this holds true, it might be considered evidence that the environment plays an important role in the development of obesity. A certain instability of decision-making preferences (and an overreliance on immediate gratification, see above) might have been present in parts of the general population for a longer time period and lead to obesity only now that the food environment has changed. This would be in line with research showing that the changes in food environment occurred almost simultaneously with the increase of obesity rates (see 1.2). In turn, to tackle the obesity epidemic, policy makers might have to promote changes in the food environment shielding obese subjects' decision-making preferences from environmental influences.



4. Are measures of behavioral impulsivity and self-report measurements of eating behavior directly related?

Given that the ‘opportunistic eating’ subscale from the TFEQ (see 1.4.2) is on the one hand related to body weight and entails on the other hand patterns of impulsive behavior that reach beyond the food context, suggests that they do. It would emphasize that domain-general aberrations in reward processing and reward-seeking behavior might underlie both, behavioral impulsivity and certain characteristics of eating behavior.

In order to answer these questions, I assessed decision-making preferences in a delay discounting task and compared the performance of lean and obese subjects (see 1.6.1). Further, I assessed, if obese subjects exhibit less stable decision-making preferences. In particular, I tested, if they differ in the degree of temporal stability of their delay discounting task performance, in the sensitivity towards changes in reward magnitude of the available choice options and lastly, if they are primed more readily by external rewarding cues incidental to the decision at hand.

In order to do so, I tested 52 participants matched for weight status (BMI either between 18.5 and 25 kg/m<sup>2</sup> or between 30 and 40 kg/m<sup>2</sup>) and gender (See fig. 5, which depicts the paradigm used). The participants underwent a computerized delay discounting task which presented them with a set of combinations of SS (always immediate) rewards and LL rewards with delays of 2, 4, 6, 9 and 12 months, e.g. 20.50 € now and 46.50 € in 4 months. They were advised to decide for the reward they preferred. After data collection, the participants’ preferences were modeled according to different psychometric functions proposed in previous research (Samuelson 1937; Mazur 1987; Laibson 1997, see 1.5) in order to find the best fit for the data.

In a second session, participants underwent the same task. However, before each decision they were presented with a rewarding picture of different context categories, namely food pictures, sexually charged pictures of couples and pictures depicting happy social scenes. They were advised to continue deciding according to their individual preference. With a repeated-measures design I tested for a direct influence of the pictures of the different context categories on the subsequent decision, i.e. a priming effect. I further tested for the temporal stability by correlating the discount rates gathered in the first session with the (unprimed) rates of the second session, and lastly, I compared the degree of sensitivity towards changes in reward magnitude between subgroups.

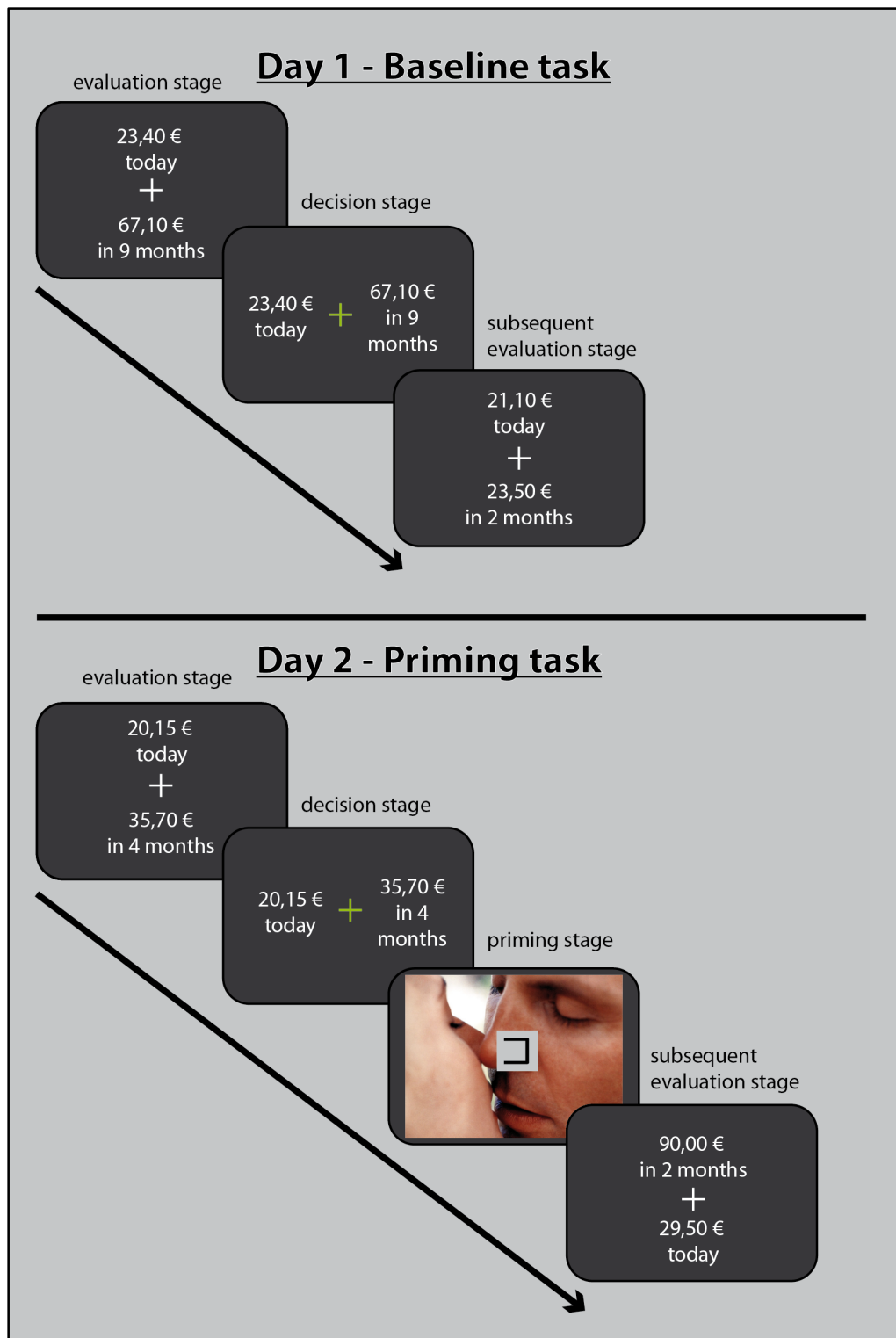


Figure 5: Paradigm used in the present thesis. Each of the 52 participants underwent two computerized delay discounting task sessions. The first session was a baseline task assessing the individual inter-temporal decision-making preference. In the evaluation stage participants were presented with a combination of a small, immediately available reward and a larger, delayed reward. They were advised to decide according to their individual preferences during the decision stage. The second session, the priming task, aimed at testing the susceptibility of decision-making preferences in the presence of incidental rewarding cues, in specific pictures depicting, (i.) couples in sexually charged situations, (ii.) happy social scenes and (iii.) food. Before each trial participants were primed with one of these pictures.

## 2. Original publication



# Incidental rewarding cues influence economic decisions in people with obesity

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Recent research suggests that obesity is linked to prominent alterations in learning and decision-making. This general difference may also underlie the preference for immediately consumable, highly palatable but unhealthy and high-calorie foods. Such poor food-related inter-temporal decision-making can explain weight gain; however, it is not yet clear whether this deficit can be generalized to other domains of inter-temporal decision-making, for example financial decisions. Further, little is known about the stability of decision-making behavior in obesity, especially in the presence of rewarding cues. To answer these questions, obese and lean participants ( $n = 52$ ) completed two sessions of a novel priming paradigm including a computerized monetary delay discounting task. In the first session, general differences between groups in financial delay discounting were measured. In the second session, we tested the general stability of discount rates. Additionally, participants were primed by affective visual cues of different contextual categories before making financial decisions. We found that the obese group showed stronger discounting of future monetary rewards than the lean group, but groups did not differ in their general stability between sessions nor in their sensitivity toward changes in reward magnitude. In the obese group, a fast decrease of subjective value over time was directly related to a higher tendency for opportunistic eating. Obese in contrast to lean people were primed by the affective cues, showing a sex-specific pattern of priming direction. Our findings demonstrate that environments rich of cues, aiming at inducing unhealthy consumer decisions, can be highly detrimental for obese people. It also underscores that obesity is not merely a medical condition but has a strong cognitive component, meaning that current dietary and medical treatment strategies may fall too short.

**Keywords:** inter-temporal decision-making, obesity, priming, delay discounting, gender, eating behavior, decision-making

## INTRODUCTION

Obesity is associated with a positive energy balance: Energy intake exceeds energy expenditure. In this context, dietary choices seem to be a crucial factor to the development and maintenance of obesity. Dietary choices can be characterized by the trade-off between highly palatable, high-calorie and easily accessible but often less healthy (e.g., convenience or take-away) food, and more healthy food contributing to the long-term maintenance of normal-weight. Paradoxically, subjects with obesity often exhibit a preference for high-calorie food despite having dietary goals to the contrary.

How can this behavior be explained? First, obesity may be paralleled by a general preference for immediately consumable rewards, i.e., highly palatable, high-calorie food. Second, choice behavior might be less stable in general and thus might often produce decisions that are not in line with subjective dietary goals. Third, choice behavior of subjects with obesity may be easily disturbed by internal or external factors such as stress or incidental rewarding cues in the environment. Differences between lean and obese people in the stability of inter-temporal decision-making preferences to external cues would have serious implications for our understanding of obesity. The abundance of food-related cues in our everyday life requires a certain robustness of decision-making preferences in order to maintain normal weight. Hence, instability in decision-making preferences is likely to be detrimental, because it might lead to the neglect of long-term dietary and weight maintenance goals and consequently to obesity.

Recent research indeed suggests obesity-associated differences in reward-based and impulsive decision-making even outside the food context. For example, obese subjects exhibited difficulties in inhibiting prepotent responses in a stop-signal task (Nederkoorn et al., 2006) and in a Go/No-Go task (Batterink et al., 2010; Kamiyo et al., 2012), and chose immediate rewards at the expense of higher future losses more often than controls in the Iowa Gambling Task (Pignatti et al., 2006; Brogan et al., 2010; Horstmann et al., 2011). In animal models it has been shown that intertemporal decision-making preferences might depend on diet, the amount of body fat mass, or the hormonal regulation of energy homeostasis. Leptin-deficient obese rats more often did not wait for a delayed but bigger portion of food (Boomhauer et al., 2013) and exhibited an overall higher degree of sensitivity to reinforcement (Buckley and Rasmussen, 2012). Moreover, the behavior of rats that have been fed by a high-fat diet was more sensitive to antidopaminergic agents than the behavior of rats fed by a standard-chow diet. After administering Haloperidol they showed a more pronounced increase in future discounting (Boomhauer and Rasmussen, 2014). This suggests that the interplay of diet and dopaminergic transmission influences intertemporal decision-making. In contrast, human studies directly investigating inter-temporal decision-making using monetary rewards have produced ambiguous results so far. Inter-temporal decision-making, i.e., deciding between immediate rewards, which are smaller in size, and rewards, which are delayed in time but have an overall higher value, essentially mirrors the trade-off in dietary choice described

above. Studies investigating inter-temporal decision-making using delay discounting tasks in obesity showed either no differences between lean and obese subjects (Nederkoorn et al., 2006), behavioral differences were accounted for by differences in socioeconomic status (Davis et al., 2010), or differences were observed in obese women only (Weller et al., 2008). Thus, it is still unclear whether obese people's preference for immediate rewards in the food context can be transferred to the context of inter-temporal decision-making with monetary rewards.

Further, little is known about the overall stability of decision preferences and their susceptibility to environmental cues in obese compared to lean people. However, research on eating behavior suggests a highly consistent positive relationship between body mass index (BMI) and the "disinhibition" subscale of the Three Factor Eating Questionnaire (TFEQ; Stunkard and Messick, 1985), also conceptualized as "opportunistic eating" (Bryant et al., 2008; Hays and Roberts, 2008; Dietrich et al., 2014; for a review on the impact of different eating behavior scores on BMI see: French et al., 2012). Opportunistic eating describes the lack of control over eating, especially in the presence of tempting external cues or situations. Recently, it has been shown experimentally that obese men respond habitually with appetitive behavior to cues signaling the availability of food reward even in the absence of subjective food motivation (Horstmann et al., 2015a). In support, the rise in the prevalence of obesity coincided with a significant change in food environment (Hill and Peters, 1998; Leung et al., 2011) with highly palatable and often unhealthy food being available virtually everywhere ("obesogenic environment"; cf. Jeffery and Utter, 2003). Consistently, previous research suggests that obese subjects' preferences in the context of eating behavior are susceptible to external cues, which are incidental to the decision at hand, e.g., a higher degree of "opportunistic eating" (Bryant et al., 2008; Hays and Roberts, 2008), signifying instability toward environmental cues, the emotional state present at the moment of decision ("emotional disinhibition," Hays and Roberts, 2008), induced stress (for a review see: Scott and Johnstone, 2012), and a stronger responsiveness to food in general (Carnell and Wardle, 2007, 2008; Garcia-Garcia et al., 2014). Moreover, opportunistic eating entails a set of personality characteristics that likely ranges beyond eating behavior (cf. Bryant et al., 2008). This raises the important question whether the susceptibility to external cues that obese subjects exhibit in the food context can be generalized to other domains of decision-making.

The present study addresses three important open questions: Firstly, we address a potential difference in inter-temporal preferences between lean and obese people. Further, we investigate the general stability of delay discounting task performance and the stochasticity of decisions in lean and obese subjects. Thirdly, we investigate differences in the susceptibility to priming between lean and obese participants by investigating the contextual stability of decision-making behavior toward external cues in both groups. In order to test for the stability of discounting task performance, the same group of participants underwent two delay discounting task sessions. Additionally, in order to test for the susceptibility of reward-based decision-making toward incidental cues, participants completed a

behavioral priming task. We administered a standard delay discounting task which entailed an additional priming session in which participants were presented with rewarding pictures of different context categories. Behavioral priming has been proven to be effective in a number of circumstances (Strahan et al., 2002; Dijksterhuis et al., 2005; Guitart-Masip et al., 2010; Bijleveld et al., 2012), including delay discounting tasks (Van den Bergh et al., 2008; Murawski et al., 2012; Kim and Zauberman, 2013; Van der Wal et al., 2013; Luo et al., 2014).

## METHODS

### Subjects

Fifty-two subjects (26 female) were recruited from the participant database of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany. They were screened with regard to inclusion and exclusion criteria during an initial telephone interview. Inclusion criteria were (i) Body Mass Index (BMI) either between 18.5 and 25 kg/m<sup>2</sup> (lean group) or 30 and 40 kg/m<sup>2</sup> (obese group), (ii) age between 18 and 35 years, and (iii) normal or corrected-to-normal vision (for demographics see Table 1). Exclusion criteria were (i) any medical condition, except for hypertension, (ii) current medication, except for anti-hypertensives and oral contraceptives, (iii) current or past diagnosis of an addictive disorder, including smoking, (iv) a history of mood disorders, eating disorders or neuropsychological disorders, including anxiety disorders and obsessive compulsive disorders (OCD).

Participants' height and weight were measured in their first laboratory session to confirm self-reported values. Further, participants completed the Beck Depression Inventory (BDI, Beck et al., 1996) and the Yale Food Addiction Scale (YFAS, Gearhardt et al., 2009), and were excluded from the study when exceeding the cut-off value of 18 on the BDI or meeting the criteria for "Food Addiction" on the YFAS.

The study was carried out in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the University of Leipzig. Participants gave their written informed consent before taking part in the study. They were reimbursed with a base payment of €7 per hour. In addition, they had a chance to win a monetary reward that depended on their choices in the experimental session (see below).

### Questionnaires

To control for the most important factors that potentially affect inter-temporal decision-making, we measured general intelligence (cf. Shamosh and Gray, 2008), education level, and household income (cf. Green et al., 1996). General intelligence was assessed by an adapted version of Raven's progressive matrices, the Wiener Matrizen-Test (Formann and Pischwanger, 1979), while secondary school qualification, professional qualification, and household income were assessed by a short education and income questionnaire (see Table 1).

Other potential confounding factors were impulsivity and sensitivity to reward (SR; De Wit et al., 2007). We assessed impulsivity using the U-P-P-S impulsivity questionnaire (Whiteside and Lynam, 2001) and the 15-item German version of the Barratt-Impulsiveness Scale 11 (Patton et al., 1995; Meule et al., 2011), and SR using the Behavioral Inhibition System and Behavioral Activation System questionnaire (BIS/BAS, Carver and White, 1994).

Delay discounting has been linked to subjective time perception (Zauberman et al., 2009; Han and Takahashi, 2012; Cooper et al., 2013). Thus, we additionally assessed participants' subjective perception of the length of objective time horizons (Zauberman et al., 2009; Cooper et al., 2013).

### Inter-temporal Decision-making

Each participant completed two experimental sessions that took place on different days (mean number of days between sessions 63.1; SEM = 5.3). In the first session (Baseline session) differences

TABLE 1 | Participant demographics.

	Lean	Obese	t	p	Male	Female	t	p
BMI	22.6 ± 1.52	34.69 ± 2.61	20.41	0.01	28.78 ± 6.18	28.51 ± 6.85	0.15	0.88
Age	25.96 ± 3.33	27.08 ± 4.2	1.06	0.3	26.88 ± 3.27	26.15 ± 4.3	0.69	0.49
WMT score	16.38 ± 4.26	17.27 ± 4.56	0.72	0.47	17.42 ± 3.64	16.23 ± 5.04	0.98	0.33
	Lean	Obese	Mann-Whitney-U	p	Male	Female	Mann-Whitney-U	P
Household income	1.5 ± 0.71	2.03 ± 0.82	216	0.02	1.77 ± 0.76	1.77 ± 0.86	332	0.91
Parents' household income	1.73 ± 0.83	1.81 ± 0.63	297.5	0.55	1.65 ± 0.69	1.88 ± 0.77	282	0.27
Contentment with current income	3.0 ± 0.87	2.81 ± 0.82	297.5	0.43	2.81 ± 0.75	2.96 ± 0.82	308	0.56
Secondary school education	2.81 ± 0.4	2.65 ± 0.63	307	0.44	2.81 ± 0.49	2.65 ± 0.56	288	0.21
Professional qualification	3.7 ± 1.26	3.31 ± 1.32	284	0.3	3.73 ± 1.12	3.27 ± 1.43	282	0.28

Demographics by gender and weight status groups (mean ± s.d.). BMI = body mass index =  $\text{bodyweight/height}^2$  in kg/m<sup>2</sup>; WMT score = Values from Wiener Matrizen Test, Formann and Pischwanger (1979); Household income = 3-point scale ranging from low (0–700€) over intermediate (701–1300€) to high (>1300€); Parent's annual household income = 3-point scale ranging from low (<30000€ per annum) over intermediate (30000–60000€ per annum) to high (>60000€ per annum); Contentment = 4-point scale ranging from "much too little" over "too little" and "sufficient" to "I don't have to worry about money"; Secondary school education = 3-point scale from "no secondary school qualification" to "A level"; Professional qualification = 5-point scale ranging from "no qualification" to "master's degree."

in inter-temporal decision-making between obese and lean subjects were assessed using a standard delay-discounting task. In the second session (Priming session), temporal stability of inter-temporal preferences was assessed as well as the influence of incidental reward cues on inter-temporal decision-making.

### Delay-discounting Task

Participants completed a computerized version of a delay-discounting task, implemented in Matlab and the Psychophysics Toolbox. In each trial, participants were asked to choose between a monetary reward that was available immediately but smaller (smaller and sooner option, SS), and a monetary reward that was larger but only available after a delay (larger and later option, LL); for example, €20 today vs. €32.50 in 4 months. Participants were instructed to choose the option that they prefer and to evaluate each decision independently of all other decisions.

### Trial procedure

Each trial started with a screen on which the two choice options, i.e., the two amounts of money together with their respective delays (SS and LL options), were presented for 3 s, one above a fixation cross at the center of the screen and one below the fixation cross. Subsequently, the same choice options were displayed in a horizontal arrangement, initiating the response stage (2 s) in which participants had to indicate their choice via a key press. Positions of SS and LL options on the screen (top/bottom and left/right) were counterbalanced across the task. Initially, 10 practice trials were presented to familiarize participants with the task procedure. During these trials the experimenter was present to answer questions and ensure that the participant understood the instructions.

### Incentive compatibility of rewards

To incentivise participants to reveal their preferences, we rendered the rewards in the task incentive-compatible: At the end of each session, each participant had a 1-in-6 chance (dice roll) to win one of the choices made during the session. If the participant won, a trial was chosen at random and the participant was paid the chosen amount at the chosen delay. The money was transferred to the participants' bank account after the respective delay.

### Baseline Session

The aim of the first experimental session was to estimate a participant's discount function. To obtain precise estimates we adopted a two-step procedure. In the first step, a titration task ("Dynamic Adjustment task," DA) was administered to obtain a first set of (approximate) parameter estimates. In the second step, a randomized choice task ("Random Choice task," RC), parameterized based on the DA task, was used to validate the parameters estimated in the DA task and to improve the precision of parameter estimates.

### Dynamic adjustment task

Discount rates vary widely across the population. The DA task approximated each participant's indifference points (*ip*) by dynamically adjusting the percentage difference (*r*) between SS (always immediate) and LL amounts using a staircase

procedure. The task terminated when the difference between the previous and the newly computed value of *r* was sufficiently small ( $<0.015$ ). We determined *ips* for six delays (1/2/4/6/9/12 months). Due to the adaptive nature of this task, trial numbers differed between subjects.

### Random choice task

In the Random Choice (RC) task participants were presented with a series of choices between SS and LL rewards, which were calibrated based on the results of the DA task. At each of six delays (1/2/4/6/9/12 months), six different amounts were shown. The amounts were multiples of the *ip* obtained in the DA task for the particular delay [0.25; 0.55; 0.85; 1.15; 1.45; 1.75]. Each amount  $\times$  delay combination was administered 4 times, resulting in 144 trials (6 amounts/delay  $\times$  6 delays  $\times$  4 repetitions). Amount/delay combinations were presented in random order.

We recorded reaction times (RT) in both tasks.

### Priming Session

In the second session participants completed the DA task followed by a RC task. In this session, only two delays (2 and 4 months) were used. The two tasks (DA and RC) provided precise estimates of participants' discount function parameters and validated them, as described above. Subsequently, participants completed a Primed Random Choice task (PRC). In the PRC task, participants' susceptibility to incidental external cues, which were hypothesized to systematically affect inter-temporal decision-making, was assessed. The cues used in the task were rewarding pictures from different context categories. The first category of images contained pictures depicting couples engaging in sexual behavior (erotic condition). Prior research showed that erotic pictures bias a person's choice behavior toward more present-oriented choices in a delay-discounting task (Van den Bergh et al., 2008; Kim and Zauberman, 2013). The second category contained images of highly palatable food items (food condition). Given the fact that obese people perceive and process food cues differently than lean people (e.g., Rothenmund et al., 2007; Wang et al., 2009; Nijs et al., 2010), we expected a differential effect of these pictures depending on weight status groups. The third and last category contained images of happy old people and family scenes (social condition), which can be conceptualized—in contrast to pictures from the first category—as secondary reinforcers. However, as obese subjects are highly stigmatized by society (for a review: Puhl and Heuer, 2009), it is likely that they perceived the pictures, similar to the pictures from the food condition, differently than lean.

### Priming image selection

All images used in the PRC task were selected from the International Affective Picture System (IAPS; Lang et al., 1997; see Supplementary Material for numbers). All pictures were of high positive valence in order to be perceived as generally rewarding (see norm ratings in Lang et al., 2008). Images were selected in two steps. In the first step, we identified a set of candidate images that fitted into one of the three context categories described above. In the second step, the candidate images were rated by an independent sample of 44 participants



with demographic characteristics comparable to the study sample [23 lean (12 female), 21 obese (11 female); mean age (obese) = 27.52 (SD = 3.66), mean age (lean) = 25.83 (SD = 3.07); mean BMI (obese) = 34.32 (SD = 2.31), mean BMI (lean) = 22.33 (SD = 1.62); *t*-test for group difference showed no significant difference for age:  $t_{(43)} = 0.68$ ;  $p > 0.05$ , but a significant group difference for BMI:  $t_{(43)} = 20.31$ ;  $p < 0.01$ ]. Ratings of perceived valence and arousal of the images were assessed using a nine-point rating scale.

For each of the three context categories described above, we selected six images such that all 18 images had high positive valence and high arousal, and that only two pictures exhibited statistically significant group differences in the mean ratings of valence or arousal [arousal rating of IAPS picture 4695 (erotic condition): men M (SD) = 1.76 (0.94), women M (SD) = 2.87 (2.26),  $t_{(42)} = 2.15$ ,  $p = 0.03$ ; valence rating of IAPS picture 7405 (food condition): lean M (SD) = 2.43 (1.85), obese M (SD) = 3.76 (1.61),  $t_{(42)} = 2.52$ ,  $p = 0.02$ ; see **Table 2** and Supplementary Material].

### Primed Random Choice task

The subsequent Primed Random Choice task (PRC) task assessed (i) whether incidental reward cues, as operationalized by the positive images, can bias participants' inter-temporal decision-making, and (ii) whether the factors weight status and gender are associated with the extent to which these images bias participants' behavior in inter-temporal decision-making.

**TABLE 2 | IAPS pictures used for priming.**

Context category	IAPS number	Motif depicted	Valence	Arousal
Erotic condition	4695	Naked couple	1.84 ± 1.41	6.53 ± 2.04
	4645	Kiss	1.68 ± 1.07	4.65 ± 2.43
	4650	Intimate naked couple	2.39 ± 1.30	5.84 ± 2.18
	4676	Naked couple	1.80 ± 1.32	6.55 ± 2.10
	4693	Naked couple	2.02 ± 1.41	5.57 ± 2.55
	4599	Intimate couple	1.89 ± 1.02	5.52 ± 2.09
Food condition	7351	Pizza	2.95 ± 2.00	3.89 ± 1.82
	7400	Chocolate	3.50 ± 1.86	3.73 ± 1.81
	7405	Muffins	3.27 ± 1.98	3.59 ± 1.83
	7470	Pancakes	3.09 ± 2.07	3.75 ± 1.93
	7480	Pasta	2.7 ± 1.8	3.20 ± 1.97
	7481	Casserole	2.45 ± 1.37	4.27 ± 2.2
Social condition	2152	Mother and infant	2.09 ± 1.96	3.32 ± 2.09
	2165	Father hugging child	1.93 ± 1.58	3.75 ± 2.29
	2370	Laughing old men	3.09 ± 2.03	3.30 ± 1.94
	2495	Old man	4.50 ± 1.84	3.25 ± 2.01
	2500	Old man	3.05 ± 1.70	3.18 ± 2.08
	2510	Laughing old lady	2.93 ± 2.25	2.95 ± 1.51

*Rating scores for priming images (mean ± s.d.). Valence ranging from 1 (=very high valence) to 9 (=very low valence) and Arousal ranging from 1 (=very low arousal) to 9 (=very high arousal).*

Each trial in the task consisted of two stages, a priming stage and a decision stage. During the priming stage, one picture from the picture set was randomly drawn and presented for a jittered duration of 3–5 s (sized 375 × 500 pixels, displayed at the center of the screen). To withdraw attention from the images during the priming stage, we included a sustained attention task: simultaneously to picture onset, a box appeared at the center of the screen (see **Figure 1**). The left and right sides of the box opened and closed again in 500 ms intervals between 3 and 4 times in random order while the picture was displayed (Tusche et al., 2010). Participants had to indicate via key press which side of the box was open. Note, however, that the images were still clearly visible and could be visually processed. Immediately following image presentation the choice options (SS/LL rewards) were displayed, followed by a response screen (see RC task above). In each trial, one of 12 LL amounts was shown, which were multiples of the indifference point estimated in the preceding RC task (0.1; 0.15; 0.65; 0.75; 0.85; 0.95; 1.05; 1.15; 1.25; 1.35; 1.85; 1.9). The large number of amounts per delay allowed us to separately investigate easy and difficult trials. We defined difficult trials as trials in which the LL amount was close the participant's indifferent point at that given delay, i.e., close to  $r = 1$  (see **Table 3**). We hypothesized that difficult decisions were the most likely to be affected by incidental rewarding cues whereas easy trials, i.e., trials in which the LL amount was far away from the indifference point, were less susceptible to influences by incidental cues. Amount/delay combinations were randomly presented, and each combination was presented three times in each of the following five conditions: (a) a neutral condition in which choices were not primed, that is, no picture was shown, (b) the erotic priming condition, (c) the food priming condition, (d) the social priming condition and, lastly, (e) a condition in which the presentation of a random picture was not followed by a delay discounting trial. All together the task session consisted of 288 trials. After completion of the PRC task, participants rated all images shown in the task using the same procedure as described for the Rating task (see above).

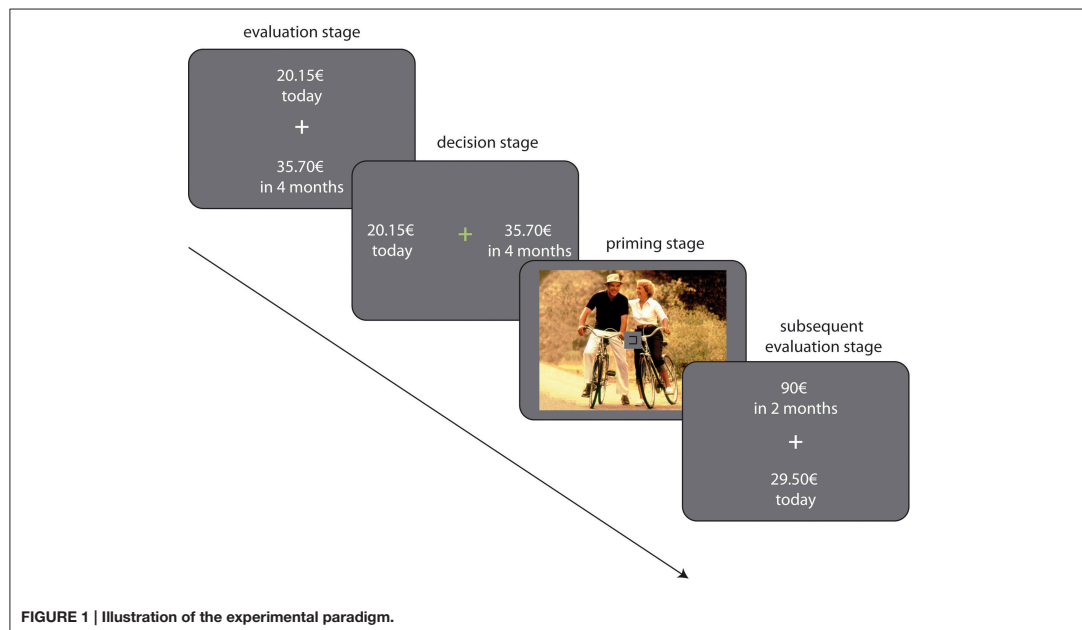
### Estimation of Discount Function

To model participants' choices, we assumed that participants value choice options according to a discount function. We further assumed that the probability of choosing a particular option in a given trial was given by the softmax function (see e.g., Kable and Glimcher, 2007). More precisely, we assumed that in each trial a participant chooses the larger, later amount (LL) with probability

$$p(LL) = \frac{1}{1 + e^{-\frac{SV(LL) - SV(SS)}{s}}}$$

where  $SV(SS)$  and  $SV(LL)$  are the subjective values of the smaller, sooner and the larger, later amount, respectively, and  $s$  is the variance of the logistic distribution ( $1/s$  is often referred to as the gain of the softmax function).

To determine the shape of participants' discount function, we fitted three different candidate models to participants' choices and compared goodness-of-fit statistics of those models. In line with previous literature, we considered the exponential model



(e.g., Samuelson, 1937), the hyperbolic model (e.g., Mazur, 1987), and the quasi-hyperbolic model (e.g., Laibson, 1997). In the exponential model, the discount function is given by

$$SV = \frac{1}{(1+r)^\tau},$$

where  $r$  denotes the discount rate and  $\tau$  denotes the delay. The hyperbolic discount function is given by

$$SV = \frac{1}{1+k\tau},$$

where  $k$  denotes the discount rate and  $\tau$  denotes the delay. Finally, in the quasi-hyperbolic model, the discount function is given by

$$SV = \beta\delta^\tau,$$

where  $\beta$  denotes the present bias,  $\delta$  denotes the discount factor and  $\tau$  denotes the delay. In contrast to the discount factor  $\delta$  describing the decrease of subjective value over time, the present bias  $\beta$  is a fixed discount of delayed rewards, irrespective of delay.

In addition to these parameters, we estimated  $s$ , the variance of the logistic distribution. The larger the parameter  $s$ , the shallower the softmax function and the lower the sensitivity of a participant's choices to differences in the values of the two choice options.

Parameters of the discount function and softmax model were estimated based on participants' choices in the RC task using maximum likelihood estimation ("fmin" function in Matlab).

## RESULTS

### Questionnaires

Obese participants were more likely to have a high or intermediate household income than lean participants but showed no significant difference in education, parents' household income, contentment with current income, and IQ scores. No gender differences were found within or between groups for any of these variables (for all details and statistics see **Table 1**).

We found no significant differences between obese and lean participants on scores or sub-scores of the Barratt Impulsiveness Scale, the U-P-P-S impulsivity questionnaire and the BIS/BAS questionnaire. However, women compared to men (across weight groups) exhibited higher scores on the Behavioral Inhibition Scale and the U-P-P-S Urgency scale and lower scores on the U-P-P-S Sensation Seeking scale (**Table 4**). Testing for gender  $\times$  weight status interactions revealed that women in the lean group had higher BIS scores than men in this group while this interaction proved only trend-significant in the obese group [lean women  $M$  (SD) = 20.31(3.88), lean men  $M$  (SD) = 17.38 (3.0),  $t_{(24)} = 2.15$ ,  $p = 0.04$ ; obese women  $M$  (SD) = 19.92 (3.73), obese men  $M$  (SD) = 17.08 (4.6),  $t_{(24)} = 1.74$ ,  $p = 0.1$ ]. Similarly, women in the lean group exhibited higher U-P-P-S Urgency scores than lean men while this interaction did not prove significant for the obese group [lean women  $M$  (SD) = 27.69 (6.0), lean men  $M$  (SD) = 23.15 (3.91),  $t_{(24)} = 2.29$ ,  $p = 0.03$ ; obese women  $M$  (SD) = 28.54 (5.8), obese men  $M$  (SD) = 24.92 (6.13),  $t_{(24)} = 1.55$ ,  $p = 0.14$ ]. No other significant interactions were found.



**TABLE 3 | Reaction times.**

	Session-task	Lean	Obese	$F_{(1, 50)}$	$p$	Male	Female	$F_{(1, 50)}$	$p$
All trials	Baseline-DA	1088	1079	0.04	0.84	1128	1040	4.31	0.04
	Baseline-RC	1030	970	2.06	0.16	1060	940	9.18	0.00
	Baseline-sum	984	973	0.15	0.70	1009	948	6.00	0.02
	Priming-DA	1036	997	0.79	0.38	1058	974	3.78	0.06
	Priming-RC	1015	942	2.73	0.11	1020	937	3.68	0.06
	Priming-PRC	945	865	3.84	0.06	951	858	5.32	0.03
	Priming-sum	944	893	2.24	0.14	962	875	6.98	0.01
Easy trials	Baseline-RC	1005	947	1.74	0.19	1026	926	8.20	0.01
	Priming-RC	974	892	3.31	0.08	977	889	3.91	0.05
	Priming-PRC	912	825	4.97	0.03	923	814	8.25	0.01
	Priming-sum	923	837	5.13	0.03	933	827	8.20	0.01
Difficult trials	Baseline-RC	1065	998	2.17	0.15	1104	959	4.28	0.04
	Priming-RC	1050	993	1.44	0.24	991	906	1.50	0.23
	Priming-PRC	962	903	1.80	0.19	1051	993	4.40	0.04
	Priming-sum	978	919	1.95	0.17	978	887	4.28	0.04

Reaction Times in milliseconds by gender and weight status groups. Difficult trials are trials in which the SS/LL combination is close to the participant's  $ip$  whereas in easy trials the SS/LL combination is further away from the  $ip$ . (EASY = for RC,  $r = 0.25 \times ip$  and  $r = 1.75 \times ip$ ; for PRC,  $r = 0.1 \times ip$ ,  $r = 0.15 \times ip$ ,  $r = 1.85 \times ip$ ,  $r = 1.9 \times ip$ ; DIFFICULT = for RC,  $r = 0.85 \times ip$ ,  $r = 1.15 \times ip$ ; for PRC,  $r = 0.85 \times ip$ ,  $r = 0.95 \times ip$ ,  $r = 1.05 \times ip$ ,  $r = 1.15 \times ip$ ). One-way ANOVAs were used to assess group differences. Priming-sum, mean of all easy/difficult trials of the Priming session.

**TABLE 4 | Impulsivity and Sensitivity to Reward/Punishment questionnaires.**

	Lean	Obese	$t$	$p$	Male	Female	$t$	$p$
U-P-P-S Urgency	25.42 ± 5.47	26.73 ± 6.13	-0.81	0.42	24.04 ± 5.12	28.12 ± 5.8	-2.69	0.01
U-P-P-S (Lack of) Perseverance	24.35 ± 4.14	24.27 ± 4.35	0.71	0.94	23.69 ± 3.4	24.92 ± 4.3	-1.15	0.26
U-P-P-S (Lack of) Premeditation	18.85 ± 3.36	18.04 ± 4.42	0.69	0.50	19.38 ± 3.79	17.5 ± 4.49	1.64	0.11
U-15-item version of the Barratt-impulsiveness Scale 11 (Patton et al., 1995; Meule et al., 2011)	34.27 ± 6.44	32.38 ± 6.79	1.03	0.31	35.15 ± 5.09	31.5 ± 7.52	2.05	0.05
BIS	18.85 ± 3.71	18.5 ± 4.35	-0.31	0.76	17.23 ± 3.8	20.12 ± 3.73	-2.76	0.01
BAS	40.73 ± 3.61	41.85 ± 4	-1.06	0.29	40.58 ± 3.96	42 ± 3.56	-1.63	0.18
BAS drive	12.38 ± 1.96	12.46 ± 2.01	-0.14	0.89	12.23 ± 2	12.62 ± 1.98	-0.70	0.49
BAS fun	12 ± 1.52	12.46 ± 1.56	-1.08	0.29	12.04 ± 1.46	12.42 ± 1.63	-0.90	0.37
BAS reward	16.35 ± 1.52	16.92 ± 1.81	-1.24	0.22	16.31 ± 1.67	16.96 ± 1.66	-1.42	0.16
BIS-15	30.19 ± 4.32	30.42 ± 5.62	-0.17	0.87	30.04 ± 4.51	30.58 ± 5.45	-0.39	0.70
BIS-15 non-planning	10.54 ± 2.73	10.42 ± 2.4	0.16	0.87	10.81 ± 2.55	10.15 ± 2.56	0.92	0.36
BIS-15 motor	10.88 ± 2.34	11.27 ± 2.71	-0.55	0.59	10.5 ± 2.32	11.65 ± 2.61	-1.69	0.10
BIS-15 attention	8.77 ± 2.05	8.73 ± 2.4	0.06	0.95	8.73 ± 2.22	8.77 ± 2.23	-0.06	0.95

Scores of different impulsivity and Sensitivity to Punishment and Reward Questionnaires, by gender and weight status groups (mean ± s.d.). BIS, Behavioral Inhibition System, Carver and White (1994); BAS, Behavioral Activation System, Carver and White (1994); BIS-11, Barrat Impulsiveness scale 11- Total score, 1985.

## Subjective Time Perception

In order to test for a potential influence of subjective time perception on inter-temporal decision-making preferences we assessed subjective perception of the length of a time interval of 2, 4, and 12 months on a visual analog scale (Zauberman et al., 2009; Cooper et al., 2013) and fitted a Power-function to the data (Cf. Kim and Zauberman, 2013). To detect potential group differences we compared the parameters  $\alpha$  and  $\beta$  taken from the Power-model between subgroups. However, the analysis revealed no significant main effect for gender [ $\alpha: F_{(1, 50)} = 3.66, p = 0.06$ ;

$\beta: F_{(1, 50)} = 0.11, p = 0.75$ ], obesity [ $\alpha: F_{(1, 50)} = 0.02, p = 0.88$ ;  $\beta: F_{(1, 50)} = 0.00, p = 0.99$ ], or for the interaction of gender  $\times$  obesity [ $\alpha: F_{(1, 48)} = 0.09, p = 0.76$ ;  $\beta: F_{(1, 48)} = 1.64, p = 0.21$ ]. Therefore, we assume that potential differences in inter-temporal preferences between groups were independent of subjective time perception.

## Model Comparisons of Discount Functions

Choices in the temporal discounting task were best described by a quasi-hyperbolic function (mean BIC values of the model fitted to

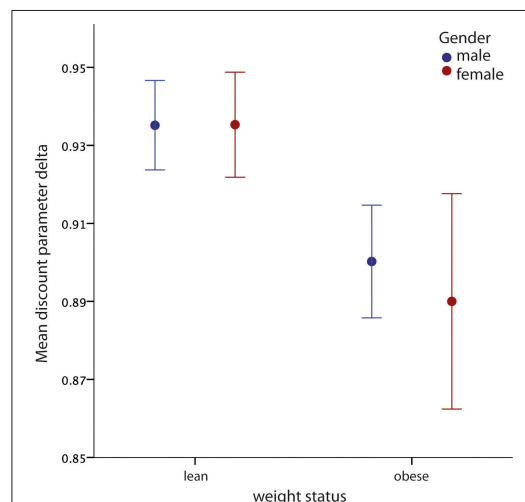
responses in RC task of the Baseline session: exponential model: 130.1 (SEM = 4.3; median = 130.8); hyperbolic model: 111.5 (SEM = 4.5; median = 106.8); quasi-hyperbolic model: 106.5 (SEM = 4.3; median = 98.8). Consequently, all following analyses were based on the quasi-hyperbolic model.

### Group Differences in Discounting

To investigate differences in inter-temporal decision-making between lean and obese as well as male and female participants we conducted group analyses on the parameters of the quasi-hyperbolic model.

The mean value across the entire sample of the present bias  $\beta$  was 0.72 (SD = 0.26). A two-way analysis of variance showed no main effect for weight status [ $F_{(1, 51)} = 1.21$ ;  $p = 0.28$ ], no main effect for gender [ $F_{(1, 51)} = 0.39$ ;  $p = 0.54$ ], and no interaction between weight status and gender [ $F_{(1, 51)} = 1.38$ ;  $p = 0.25$ ].

The mean value of the discount factor  $\delta$  was 0.92 (SD = 0.07). A two-way analysis of variance showed a main effect for weight status group [ $F_{(1, 51)} = 5.02$ ;  $p = 0.03$ ], with obese participants exhibiting lower values of  $\delta$ , meaning that obese participants discount future rewards at a higher rate per unit of time delay than lean (see Figure 2). If this effect were dependent on socioeconomic status one would have expected an effect in the opposite direction given that members of the obese group had on average higher incomes than members of the lean group. The analysis did not show a significant effect for gender [ $F_{(1, 51)} = 0.079$ ;  $p = 0.78$ ], and no significant interaction between weight status group and gender [ $F_{(1, 51)} = 0.084$ ;  $p = 0.77$ ].



**FIGURE 2 | Main effect of obesity on delay discounting parameter  $\delta$ .** Obese subjects had lower values of the discounting parameter  $\delta$ , independent of gender. Error bars indicate standard errors of means (SEM).

### Relationship Between Discount Parameters and Questionnaire Data

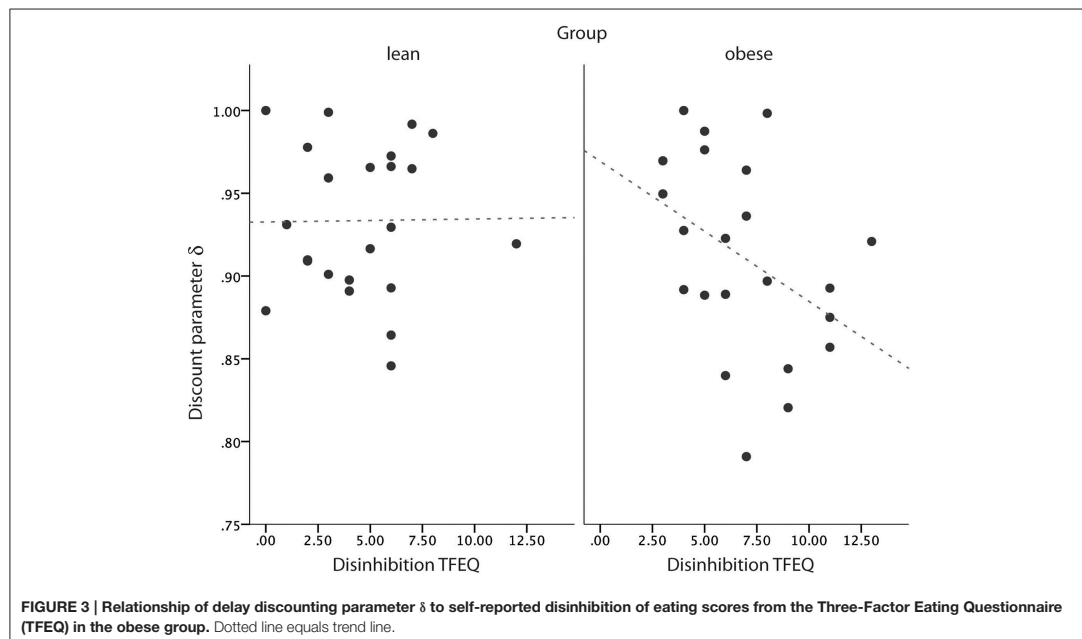
Given that decisions in the eating behavior context often resemble inter-temporal decision-making dilemmas, we aimed at testing if delay discounting task performance was directly related to disinhibition scores from the Three-Factor Eating Questionnaire (TFEQ). We correlated scores of the subscale disinhibition, which measures the degree of a propensity to overeat in an obesogenic environment, with  $\delta$  taken from the quasi-hyperbolic model. We found that in obese in contrast to lean subjects, the discount factor  $\delta$  scores were inversely correlated to disinhibition scores reflecting opportunistic eating [see Figure 3, Spearman's  $\rho$  (obese) =  $-0.46$ ,  $p = 0.03$ ; Spearman's  $\rho$  (lean) =  $0.06$ ,  $p = 0.79$ ; two-tailed]. In other words, we found that a fast decrease of subjective value over time is directly related to a tendency to opportunistic eating. This relationship holds true for obese participants only.

Based on a strong conceptual overlap of delay discounting and self-report measurements of impulsivity/sensitivity to reward, we further hypothesized the existence of a relationship between measures of these two concepts. The present bias  $\beta$  was positively correlated with BAS reward scores, indicating the degree of a person's positive response to a reward—anticipated or occurring—, in the lean group [Spearman's  $\rho$  (lean) =  $0.44$ ;  $p = 0.03$ ; two-tailed] but not in the obese group [Spearman's  $\rho$  (obese) =  $0.08$ ,  $p = 0.68$ ; two-tailed]. Conversely,  $\beta$  was negatively correlated with U-P-P-S Urgency scores, measuring the strength of experienced impulses, especially under negative affect, in the obese group [Spearman's  $\rho$  (obese) =  $-0.43$ ;  $p = 0.03$ ; two-tailed], but entirely uncorrelated in the lean group [Spearman's  $\rho$  (lean) =  $-0.001$ ,  $p = 0.99$ ; two-tailed]. The discount factor  $\delta$  was negatively correlated with BAS reward scores in the entire sample (Spearman's  $\rho = -0.46$ ;  $p = 0.01$ ; two-tailed). *Post-hoc* analyses showed that this effect was stronger in the obese group (Spearman's  $\rho$  (obese) =  $-0.54$ ,  $p = 0.01$ ; two-tailed) and marginally failed to reach significance in the lean group [Spearman's  $\rho$  (lean) =  $-0.38$ ,  $p = 0.06$ ; two-tailed].

Finally, across groups we found that men, in contrast to women, exhibited a positive correlation between BIS-15 motor impulsivity scores and the stochasticity parameter  $s$  [Spearman's  $\rho$  (men) =  $0.46$ ,  $p = 0.02$ ; Spearman's  $\rho$  (women) =  $0.15$ ,  $p = 0.46$ ; all two-tailed]. Men, in contrast to women, exhibited a direct relationship between a tendency to act without thinking (motor impulsivity) and a low sensitivity toward changes in reward magnitude in a delay discounting task, as described by high values of  $s$ .

### Reaction Times and Inter-temporal Decision-making

We also investigated the relation between reaction times (RT) and inter-temporal decision-making. Our analysis was based on a correlational analysis of RTs and discount factors ( $\delta$  parameter in the discount function), quantifying the rate of devaluation of future rewards. Discount factors were computed separately for each of the two tasks in the priming session. RTs exhibited significant gender differences in both sessions, with



women exhibiting faster RTs (for detailed statistics see **Table 3**). Additionally, RTs in the PRC task of the Priming session were faster by trend in the obese group [ $F_{(1, 50)} = 3.84, p = 0.06$ ]. This difference was significant when considering easy trials only [ $F_{(1, 50)} = 4.97, p = 0.03$ ]. There was no significant difference between RTs in the different priming conditions.

To test if the observed differences in RTs were related to discounting behavior, we correlated RTs with participants' discount factors in the RC and the PRC task of the priming session, separately for gender groups. We found that for men, independent of the weight status, RTs were positively correlated with discount factors, implying that fast responses during inter-temporal choices were associated with higher rates of discounting of future rewards [for the RC task: Spearman's  $\rho$  (men) = 0.44,  $p = 0.03$ ; Spearman's  $\rho$  (women) = 0.24,  $p = 0.24$ ; all two-tailed; for the PRC task: (a) neutral condition: Spearman's  $\rho$  (men) = 0.49,  $p = 0.01$ ; Spearman's  $\rho$  (women) = 0.28,  $p = 0.17$ ; all two-tailed; (b) social condition (Spearman's  $\rho$  (men) = 0.42,  $p = 0.05$ ; Spearman's  $\rho$  (women) = 0.3,  $p = 0.14$ ; all two-tailed; (c) erotic condition: (Spearman's  $\rho$  (men/women) = 0.34/0.16; all  $p > 0.05$ ; all two-tailed; (d) food condition Spearman's  $\rho$  (men/women, food) = 0.39/0.12; all  $p > 0.05$ ; all two-tailed].

### General Stability of Inter-temporal Decision-making Preferences

We investigated two, presumably independent, aspects of stability in inter-temporal decision-making preferences. First, we

examined the general stability of inter-temporal decision-making preferences. We tested for the longitudinal stability of preferences (between sessions) and for the stochasticity of decision-making, a marker of the consistency of decisions and thus the stability of internal value representations.

To examine participants' temporal stability of decision-making preferences, we compared discount factors between sessions. We applied a Fisher-r-to-z transformation to the coefficients of correlation between discount factors in the Baseline and the Priming session. We found that correlations of discount factors between sessions were high and not significantly different between the lean and obese group [ $Z = 0.52, p = 0.6$ , two-tailed; Pearson's  $r$  (lean) = 0.89; Pearson's  $r$  (obese) = 0.92; correlations significant at the  $p < 0.01$  level], and men and women [ $Z = 0.52, p = 0.06$ , two-tailed; Pearson's  $r$  (women) = 0.89; Pearson's  $r$  (men) = 0.92; correlations significant at the  $p < 0.01$  level]. This suggests that inter-temporal preferences in both groups were relatively stable over time in the absence of incidental rewarding cues.

Next, we tested for differences in the degree of stochasticity of participants' behavior, as captured by parameter  $s$  in the quasi-hyperbolic discount function. Analysis of group differences for parameter  $s$ , a marker for the consistency of decisions and thus the internal stability of value representations [ $M$  (SD) = 4.24 (5.45)], revealed no significant main effect for obesity [ $F_{(1, 51)} = 0.23; p = 0.64$ ] or gender [ $F_{(1, 51)} = 0.55; p = 0.46$ ] and no significant interaction [ $F_{(1, 51)} = 1.32; p = 0.26$ ], suggesting that the stability of internal value representations in obese and lean

participants does not differ in the absence of contextual cues (see above).

In sum, analysis of the general stability of inter-temporal decision-making preferences—temporal stability and consistency of decisions—revealed no differences between lean and obese.

### Susceptibility of Inter-temporal Decision-making to Incidental Rewarding Pictures—Impact of Priming

Next, we investigated the influence of external factors on inter-temporal decision-making to measure the stability of inter-temporal preferences with regard to changes of context. To do so, we tested if incidental rewarding stimuli (the affective pictures from different context categories) had a significant priming effect on inter-temporal decision-making. Further, we analyzed whether this priming effect was systematically related to weight status and gender.

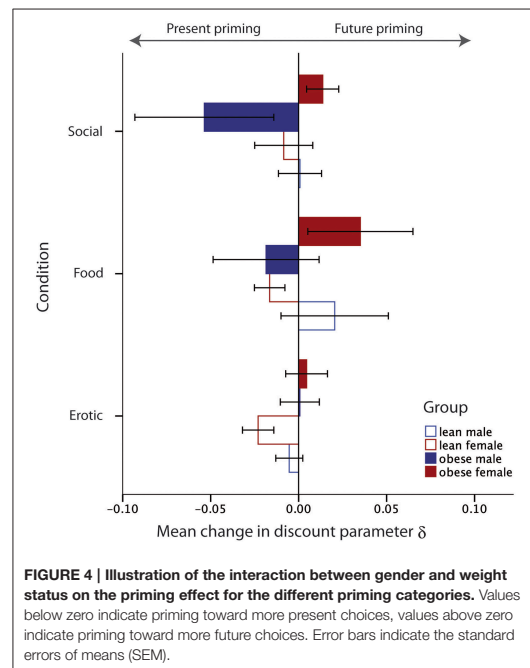
Our analysis was based on a comparison of discount factors (parameter  $\delta$ ) between priming conditions, with the neutral (non-priming) condition as an intra-individual baseline measure. Separate repeated-measures ANOVAs were performed to compare potential priming effects for each of several categories of images (erotic, food, social, see Table 2) between gender and weight status groups.

First, we investigated the within-subject effect of priming in separate ANOVAs for each image category in the entire sample. The analysis revealed no significant priming effect for any of the image categories [ $F_{\text{food}(1, 47)} = 0.15, p = 0.7$ ;  $F_{\text{social}(1, 47)} = 0.02, p = 0.88$ ], even though the erotic priming effect revealed trend-significance [ $F_{\text{erotic}(1, 48)} = 3.24, p = 0.08$ ]. There was no significant main effect on priming for weight status in any category [ $F_{\text{erotic}(1, 47)} = 2.31, p = 0.14$ ;  $F_{\text{food}(1, 46)} = 0.23, p = 0.64$ ;  $F_{\text{social}(1, 46)} = 0.03, p = 0.87$ ] nor was there a main effect for gender [ $F_{\text{erotic}(1, 47)} = 0.03, p = 0.87$ ;  $F_{\text{food}(1, 46)} = 0.79, p = 0.38$ ;  $F_{\text{social}(1, 46)} = 2.45, p = 0.13$ ].

Second, we tested for gender  $\times$  obesity interactions. We found a gender  $\times$  obesity effect for the food category as well as the social category [ $F_{\text{food}(1, 44)} = 4.21, p = 0.04$ ;  $F_{\text{social}(1, 44)} = 4.24, p = 0.04$ ], but no effect for the erotic category [ $F_{\text{erotic}(1, 44)} = 0.09, p = 0.76$ ]. The interaction revealed that obese women's choices, after exposure to visual cues from the food and social category, tended to be more future-oriented while obese men's choices were more present-oriented (see Figure 4).

### Relationship Between Priming Effect Size and Self-Report Measures of Impulsivity, Sensitivity to Reward (SR), General Intelligence, and Inter-temporal Preferences

We further analyzed whether the strength of subjects' susceptibility toward external rewarding cues was related to self-report measures of impulsivity (BIS-15 and U-P-P-S impulsivity questionnaire), SR (BIS/BAS scores), general intelligence (Wiener Matrizen Test), and parameters of the discount function. No significant correlation between the



**FIGURE 4 | Illustration of the interaction between gender and weight status on the priming effect for the different priming categories.** Values below zero indicate priming toward more present choices, values above zero indicate priming toward more future choices. Error bars indicate the standard errors of means (SEM).

priming effect and self-report measures of impulsivity, SR or general intelligence was found in any category (all Pearson and rank correlations  $p > 0.05$ ). However, we found a significant correlation between the priming effect of erotic images with  $\beta$ , the parameter capturing a “present bias” in discounting (Spearman's  $\rho = 0.45, p = 0.01$ ). Single correlation analyses showed that the effect was strongly driven by the lean group [Spearman's  $\rho$  (lean) = 0.6,  $p = 0.01$ ; Spearman's  $\rho$  (obese) = 0.15,  $p = 0.53$ ] and men [Spearman's  $\rho$  (men) = 0.57,  $p = 0.01$ ; Spearman's  $\rho$  (women) = 0.28,  $p = 0.2$ ] and most pronounced in lean men [Spearman's  $\rho$  (lean men) = 0.83,  $p = 0.01$ ]. This means that the lower the “present bias” in discounting, the higher the degree of susceptibility of inter-temporal choices to priming by erotic pictures, especially in lean men. However, the results have to be treated with caution given that the priming effect for erotic pictures proved only trend-significant (see above).

## DISCUSSION

We investigated differences in inter-temporal choice between people with obesity and lean control subjects. Our results showed that obese subjects, independent of gender, devalued future rewards at higher rates than healthy controls. The groups did not differ in the stability of discounting behavior over time. Further, we showed that a higher tendency of opportunistic eating was associated with a higher reliance on immediate monetary rewards in the obese group. In addition, we found that obese subjects were more susceptible to external cues. This effect was gender-specific

in its direction: food and social cues reduced discounting in obese women while they increased discounting in obese men. These findings indicate that the specific context of decision-making may play a substantial role in obesity and that this effect is not attributable to less stability in value representations in obese people.

### Higher Discount Rates in Obese Subjects

An overreliance on immediate gratification can be assumed in the context of dietary choices in obesity (Epstein et al., 2010). Interestingly, our finding that obese in contrast to lean participants also exhibited a strong preference for immediately available monetary rewards suggests obesity-associated alterations in domain-general decision-making processes. A strong preference for immediate rewards might be caused by differences in the computation of the value of the choice options. Recent studies showed structural and functional alterations of components of the valuation system in obesity (Stoeckel et al., 2008; Horstmann et al., 2011; Mueller et al., 2011; Nummenmaa et al., 2012; García-García et al., 2014). Hence, one possibility is that the common mechanism underlying the domain-general preference for immediate rewards is an altered computation of decision values in individuals with obesity. Dopamine has been shown to play an important role in cost-benefit decision-making (Treadway et al., 2012) and motivation (e.g., Hoebel et al., 2007; Kobayashi and Schultz, 2014). Human obesity and diet-induced obesity as well as a prolonged high-fat diet in rodents have been shown to produce pronounced alterations in several components of dopaminergic transmission (Cone et al., 2013; Narayanaswami et al., 2013; Sharma and Fulton, 2013; Horstmann et al., 2015b) and the modulatory endocannabinoid system (Cheer et al., 2004; Bello et al., 2012). Convergent evidence highlights alterations in dopamine D2 receptor availability, dopaminergic tone, and the efficacy of dopamine transporter (DAT). Thus, function of structures receiving dopaminergic input and playing an important role in inter-temporal choice such as ventral striatum, amygdala, and prefrontal cortex might be compromised in obesity. In the context of inter-temporal decision-making, subjective value of the options is represented in ventral striatum, medial prefrontal cortex and posterior cingulate cortex (Kable and Glimcher, 2007, 2010), while activity in anterior cingulate cortex supports the context-sensitive dynamic adjustment of preference functions via input from amygdala, posterior cingulate cortex, and hippocampus (Peters and Büchel, 2010). Recent research suggests an even more pronounced role of the basolateral amygdala as a central integrator of reward value, its history and cost parameters (Wassum and Izquierdo, 2015), which might be of particular interest in the context of inter-temporal reward-based decision-making. Altered dopaminergic input into these areas might thus produce (a) a general shift in delay discounting preferences and (b) a higher susceptibility of choice parameters to the influence of external cues. In line with this hypothesis, other studies demonstrated alterations in reward-based decision-making or impulse-control in obese populations. For example, obese people exhibited altered performance in the Iowa Gambling Task (Pignatti et al., 2006; Brogan et al., 2010;

Horstmann et al., 2011; Koritzky et al., 2012), the stop signal task (Nederkorn et al., 2006) and a Go/No-Go task (Batterink et al., 2010; Kamiyo et al., 2012) when compared to their lean counterparts.

Prior studies showed that obese women discount future rewards steeper than lean women while no difference was observed for men (Weller et al., 2008). In contrast, we found comparable obesity-associated differences in discount rates in both men and women. Our study differs in important methodological aspects from the previous ones, which might have contributed to the differential findings. In their task, Weller and colleagues used hypothetical rewards with no real consequences for participants, as well as very large monetary amounts (\$500 up to \$50,000) and very long delays (up to 10 years). Even though the impact of the influence of reward type (real vs. hypothetical rewards) remains debated (Johnson and Bickel, 2002; Madden et al., 2003, 2004; Hinvest and Anderson, 2010), recent results showed that the use of real monetary incentives in delay discounting tasks led to shallower delay discounting functions when compared to hypothetical monetary incentives (Hinvest and Anderson, 2010). In addition, it has been shown in a delay discounting task that higher monetary amounts led to shallower discount functions, which has been termed the “magnitude effect” (Thaler, 1981; Green et al., 1999; Estle et al., 2006; Mitchell and Wilson, 2010). In our study, we used smaller monetary amounts, but participants had the chance to win one of the choices made during the experiment, creating real incentives for task performance and making our task more realistic.

Further, we carefully matched gender and weight status groups for general intelligence, age, income, and education, as these factors seem to be linked to inter-temporal decision-making preference (Green et al., 1996; Shamosh et al., 2008; Davis et al., 2010). Another possible confound that we can rule out is general differences in time perception (Takahashi, 2005; Wittmann and Paulus, 2008; Zauberman et al., 2009), as our study explicitly controlled for subjective time perception and found no differences between groups.

Having established general differences in inter-temporal choice between obese and lean people, our results further provide first evidence for a direct link between characteristics of eating behavior and inter-temporal preferences. A higher tendency of opportunistic eating was associated with a higher reliance on immediate monetary rewards in the obese group. Note, however, that the association between general inter-temporal decision-making preference and BMI cannot be fully explained by “opportunistic eating,” since correlation strength was only moderate. Other obesogenic characteristics of behavior, not covered by the “opportunistic eating” scale, are most likely additionally associated with general inter-temporal decision-making preference. These might include factors adding to an imbalance of energy uptake and energy expenditure, e.g., a lack of physical activity. In order to clarify the mechanisms by which inter-temporal decision-making preference exerts an influence on body weight, future research should thus directly address the relationships between inter-temporal decision-making preferences and the composition of diet, e.g., the variety of the diet (McCrory et al., 1999), the amount of

consumed ultra processed and convenience foods (St-Onge et al., 2003; Monteiro et al., 2011), and the composition of calorie intake (Austin et al., 2011), as well as the amount of physical activity.

### Susceptibility to Environmental Cues

Our second major finding was an enhanced susceptibility to environmental cues in inter-temporal decisions for obese people as compared to healthy controls. Priming with rewarding images led to a differential effect in obese women compared to obese men. More specifically, after priming with visually depicted social scenes (family and happy old people) and food, obese men's choices became more present-oriented whereas obese women's choices became more future-oriented. Lean subjects did not show any significant susceptibility to the visual cues.

Priming has been shown to be effective in a number of circumstances, including inter-temporal choice (Van den Bergh et al., 2008; Zauberman et al., 2009; Murawski et al., 2012; Luo et al., 2014). It is based on the assumption that the presentation with an environmental cue biases the response to a subsequent cue, which can be entirely unrelated, due to an implicit memory effect activating association networks (Bargh, 1990; Tulving and Schacter, 1990; Chartrand and Bargh, 1996) or to the fast and automatic extraction of decision-relevant aspects of the stimuli during exposure (Bode et al., 2014).

Recent research suggests that the direction of priming effects observed in a general population depend on the perceived valence of the cues utilized. The induction of positive and negative affect by visual cues, i.e., happy and sad faces, has been shown to lead to more present-oriented choices for positive cues and more future-oriented choices for negative cues (Luo et al., 2014). Given the opposing direction in obese men and women, it is reasonable to assume that differential valuation and processing of the presented cues might moderate the effect.

Obese men, on the one hand, were biased toward immediate monetary rewards with images of social scenes and food. This is in line with our expectations, as food items in particular have a high rewarding value in obesity (Rothmund et al., 2007; Wang et al., 2009; Nijs et al., 2010) and strong rewarding cues have been shown to bias a normal population toward immediate rewards (Van den Bergh et al., 2008; Murawski et al., 2012; Cooper et al., 2013; Van der Wal et al., 2013).

The future priming effect in obese women on other hand might be explained by a differential perception of the cues utilized. We hypothesize that obese women might have perceived the presented social and food cues as more negative than obese men due to differences in the implicit attitudes toward them. Note that while such attitude biases were not expressed in the *explicit* valence ratings for the presented pictures that did not differ between gender groups, the persistence of *implicit* attitude differences has been described before.

Obese women have been shown to exhibit more negative implicit associations with food, especially high-fat food items (Roefs and Jansen, 2002). Furthermore, it has been shown that women in general had stronger inhibitory DLPFC activation in response to food stimuli, leading to less *ad libitum* food intake (Cornier et al., 2010).

This might apply to social cues as well. Research shows that obese women in particular seem to suffer from the stigmatization of obesity (Puhl and Heuer, 2009), especially in relationship and social settings (Chen and Brown, 2005; Sheets and Ajmere, 2005). Given that the presented cues mirror typical social and relationship settings, obese women might have evaluated the cues implicitly as more negative than their male counterparts.

Luo et al. (2014) suggested a mechanism by which negative affect could change decision-making preferences relying on research showing that negative affect led to more goal-directed decision strategies (Forgas, 1991) and systematic processing (Loewenstein and Lerner, 2003). They used priming with sad faces to induce negative affect and attributed priming toward more future-oriented decisions to an 'inhibition spillover effect'. This theory states that inhibition in one domain, e.g., inhibiting the emotional response to an affective visual cue, leads to an inhibition in other domains, e.g., motor responses. This effect has been hypothesized to be mediated by the right inferior frontal cortex (rIFC), which is involved in domain-general inhibitory processes (Berkman et al., 2009).

In the same way, the "inhibition spillover" effect could explain the effect of environmental cues, implicitly valued negatively by obese women, on inter-temporal choice in our study. If some stimuli were perceived implicitly as negative and not as rewarding, this may have necessitated an inhibition of the triggered emotional response, and an "inhibition spillover" might have reversed the expected decision pattern, priming obese women toward more future-oriented choices.

Our results reveal a higher degree of susceptibility toward environmental cues in obese. In obese men, in accordance with findings in general populations, priming led to more immediate choices. In contrast, obese women were primed toward more future choices. For obese men, our results indicate that rewarding environmental cues might be detrimental in that they lead to an overreliance on immediate rewards in today's enhanced food environment aiming at inducing dietary short-sightedness (Hill and Peters, 1998). For obese women, in contrast, our results reveal a decision-making pattern that appears to be rather protective in such an environment. However, in (other) addictive disorders the degree of consumption of the drug of choice is not directly linked to its implicit evaluation (Larsen et al., 2012), which is often negative (Wiers et al., 2002; Roefs et al., 2011). Transferred to the context of obesity, this might signify that the degree of consumption of food is not linked to its implicit evaluation. Thus, further research is required to establish a causal link between such a priming effect and consumption of food in the natural environment.

### Conclusions

Our findings contribute to a growing body of literature that challenges the notion that obesity is purely a medical condition (Rippe and McInnis, 2001) but instead point to a strong cognitive dimension, which can be shaped by environmental factors. Subjects with obesity exhibit impairments in different cognitive domains such as executive function, working memory (Fitzpatrick et al., 2013), learning tasks (Coppin et al., 2014) and behavioral control (Horstmann et al., 2015a), possibly mediated



by non-linear changes within the central balance of phasic and tonic dopaminergic signaling (Wang et al., 2001; de Weijer et al., 2011; Dunn et al., 2012; Guo et al., 2014; Horstmann et al., 2015a). Importantly, this indicates that treatment options focusing on dietary changes and induction of physical activity only might fall far too short. Instead, treatment might need to address executive functioning (Hall et al., 2013; McClure and Bickel, 2014), impulse control, and working memory training (Shamosh and Gray, 2008; Shamosh et al., 2008; Bickel et al., 2011) in order to shield decisions from environmental influences. Further, pharmacological treatment options that target alterations that might underlie both detrimental eating behavior and cognitive impairments might prove successful. Possible targets are dopaminergic transmission (e.g., Horstmann et al., 2015a),  $\mu$ -opioid receptor transmission (Cambridge et al., 2013; Laurent et al., 2014; Sanchez-Roige et al., 2014) as well as the endocannabinoid receptor system (Boomhower et al., 2013; Watkins and Kim, 2015). These systems are most likely to mutually affect reward-based decision-making in goal-directed behavior (see e.g., Labouëbe et al., 2013).

## REFERENCES

- Austin, G., Ogden, L., and Hill, J. (2011). Trends in carbohydrate, fat, and protein intakes and association with energy intake in normal-weight, overweight, and obese individuals: 1971–2006. *Am. J. Clin. Nutr.* 94, 836–843. doi: 10.3945/ajcn.110.006141
- Bargh, J. A. (1990). “Auto motives. Preconscious determinants of social interaction,” in *Handbook of Motivation and Cognition: Foundations of Social Behavior*, Vol. 2, eds R. M. Sorrentino and E. T. Higgins (New York, NY: Guilford Press), 93–130.
- Batterink, L., Yokum, S., and Stice, E. (2010). Body mass correlates inversely with inhibitory control in response to food among adolescent girls: an fMRI study. *Neuroimage* 52, 1696–1703. doi: 10.1016/j.neuroimage.2010.05.059
- Beck, A. T., Steer, R. A., and Brown, G. (1996). *Manual for the Beck Depression Inventory (BDI-II)*. San Antonio, TX: Psychological Corporation.
- Bello, N. T., Coughlin, J. W., Redgrave, G. W., Ladenheim, E. E., Moran, T. H., and Guarda, A. S. (2012). Dietary conditions and highly palatable food access alter cannabinoid receptor expression and binding density. *Physiol. Behav.* 105, 720–726. doi: 10.1016/j.physbeh.2011.09.021
- Berkman, E. T., Burkland, L., and Lieberman, M. D. (2009). Inhibitory spillover: intentional motor inhibition produces incidental limbic inhibition via right inferior frontal cortex. *Neuroimage* 47, 705–712. doi: 10.1016/j.neuroimage.2009.04.084
- Bickel, W. K., Yi, R., Landes, R. D., Hill, P. F., and Baxter, C. (2011). Remember the future: working memory training decreases delay discounting among stimulant addicts. *Biol. Psychiatry* 69, 260–265. doi: 10.1016/j.biopsych.2010.08.017
- Bijleveld, E., Custers, R., and Aarts, H. (2012). Adaptive reward pursuit: how effort requirements affect unconscious reward responses and conscious reward decisions. *J. Exp. Psychol. Gen.* 141, 728–742. doi: 10.1037/a0027615
- Bode, S., Bennett, D., Stahl, J., and Murawski, C. (2014). Distributed patterns of event-related potentials predict subsequent ratings of abstract stimulus attributes. *PLoS ONE* 9:e109070. doi: 10.1371/journal.pone.0109070
- Boomhower, S. R., and Rasmussen, E. B. (2014). Haloperidol and rimobant increase delay discounting in rats fed high-fat and standard-chow diets. *Behav. Pharmacol.* 25, 705–716. doi: 10.1097/FBP.0000000000000058
- Boomhower, S. R., Rasmussen, E. B., and Doherty, T. S. (2013). Impulsive-choice patterns for food in genetically lean and obese Zucker rats. *Behav. Brain Res.* 241, 214–221. doi: 10.1016/j.bbr.2012.12.013
- Brogan, A., Hevey, D., and Pignatti, R. (2010). Anorexia, bulimia, and obesity: shared decision making deficits on the Iowa Gambling Task (IGT). *J. Int. Neuropsychol. Soc.* 16, 711–715. doi: 10.1017/S1355617710000354
- Bryant, E. J., King, N. A., and Blundell, J. E. (2008). Disinhibition: its effects on appetite and weight regulation. *Obes. Rev.* 9, 409–419. doi: 10.1111/j.1467-789X.2007.00426.x
- Buckley, J. L., and Rasmussen, E. B. (2012). Obese and lean Zucker rats demonstrate differential sensitivity to rates of food reinforcement in a choice procedure. *Physiol. Behav.* 108, 19–27. doi: 10.1016/j.physbeh.2012.10.001
- Cambridge, V. C., Ziauddeen, H., Nathan, P. J., Subramaniam, N., Dods, C., Chamberlain, S. R., et al. (2013). Neural and behavioral effects of a novel Mu opioid receptor antagonist in binge-eating obese people. *Biol. Psychiatry* 73, 887–894. doi: 10.1016/j.biopsych.2012.10.022
- Carnell, S., and Wardle, J. (2007). Measuring behavioural susceptibility to obesity: validation of the child eating behaviour questionnaire. *Appetite* 48, 104–113. doi: 10.1016/j.appet.2006.07.075
- Carnell, S., and Wardle, J. (2008). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am. J. Clin. Nutr.* 88, 22–29.
- Carver, C. S., and White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the BIS/BAS Scales. *J. Pers. Soc. Psychol.* 67, 319–333. doi: 10.1037/0022-3514.67.2.319
- Chartrand, T. L., and Bargh, J. A. (1996). Automatic activation of impression formation and memorization goals: nonconscious goal priming reproduces effects of explicit task instructions. *J. Pers. Soc. Psychol.* 71, 464–478. doi: 10.1037/0022-3514.71.3.464
- Cheer, J. F., Wassum, K. M., Heien, M. L. A. V., Phillips, P. E. M., and Wightman, R. M. (2004). Cannabinoids enhance subsecond dopamine release in the nucleus accumbens of awake rats. *J. Neurosci.* 24, 4393–4400. doi: 10.1523/JNEUROSCI.0529-04.2004
- Chen, E. Y., and Brown, M. (2005). Obesity stigma in sexual relationships. *Obes. Res.* 13, 1393–1397. doi: 10.1038/oby.2005.168
- Cone, J. J., Chartoff, E. H., Potter, D. N., Ebner, S. R., and Roitman, M. F. (2013). Prolonged high fat diet reduces dopamine reuptake without altering DAT gene expression. *PLoS ONE* 8:e58251. doi: 10.1371/journal.pone.0058251
- Cooper, N., Kable, J. W., Kim, B. K., and Zauberman, G. (2013). Brain activity in valuation regions while thinking about the future predicts individual discount rates. *J. Neurosci.* 33, 13150–13156. doi: 10.1523/JNEUROSCI.0400-13.2013
- Coppin, G., Nolan-Poupart, S., Jones-Gotman, M., and Small, D. M. (2014). Working memory and reward association learning impairments in obesity. *Neuropsychologia* 65, 146–155. doi: 10.1016/j.neuropsychologia.2014.10.004

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## SUPPLEMENTARY MATERIAL

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- Cornier, M., Salzberg, A., and Endly, D. (2010). Sex-based differences in the behavioral and neuronal responses to food. *Physiol. Behav.* 99, 538–543. doi: 10.1016/j.physbeh.2010.01.008
- Davis, C., Pate, K., Curtis, C., and Reid, C. (2010). Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite* 54, 208–213. doi: 10.1016/j.appet.2009.11.002
- de Weijer, B. A., van de Giessen, E., van Amelsvoort, T. A., Boot, E., Braak, B., Janssen, I. M., et al. (2011). Lower striatal dopamine D2/3 receptor availability in obese compared with non-obese subjects. *EJNMMI Res.* 1:37. doi: 10.1186/2191-219X-1-37
- De Wit, H., Flory, J. D., Acheson, A., McCloskey, M., and Manuck, S. B. (2007). IQ and nonplanning impulsivity are independently associated with delay discounting in middle-aged adults. *Pers. Individ. Dif.* 42, 111–121. doi: 10.1016/j.paid.2006.06.026
- Dietrich, A., Federbusch, M., Grellmann, C., Villringer, A., and Horstmann, A. (2014). Body weight status, eating behavior, sensitivity to reward/punishment, and gender: relationships and interdependencies. *Front. Psychol.* 5:1073. doi: 10.3389/fpsyg.2014.01073
- Dijksterhuis, A., Smith, P. K., van Baaren, R. B., and Wigboldus, D. H. J. (2005). The unconscious consumer: effects of environment on consumer behavior. *J. Consum. Psychol.* 15, 193–202. doi: 10.1207/s15327663jcp1503\_3
- Dunn, J. P., Kessler, R. M., Feurer, I. D., Volkow, N. D., Patterson, B. W., Ansari, M. S., et al. (2012). Relationship of dopamine type 2 receptor binding potential with fasting neuroendocrine hormones and insulin sensitivity in human obesity. *Diabetes Care* 35, 1105–1111. doi: 10.2337/dc11-2250
- Epstein, L. H., Salvy, S. J., Carr, K. A., Dearing, K. K., and Bickel, W. K. (2010). Food reinforcement, delay discounting and obesity. *Physiol. Behav.* 100, 438–445. doi: 10.1016/j.physbeh.2010.04.029
- Estle, S. J., Green, L., Myerson, J., and Holt, D. D. (2006). Differential effects of amount on temporal and probability discounting of gains and losses. *Mem. Cognit.* 34, 914–928. doi: 10.3758/BF03193437
- Fitzpatrick, S., Gilbert, S., and Serpell, L. (2013). Systematic review: are overweight and obese individuals impaired on behavioural tasks of executive functioning? *Neuropsychol. Rev.* 23, 138–156. doi: 10.1007/s11065-013-9224-7
- Forgas, J. P. (1991). Affective influences on partner choice: role of mood in social decisions. *J. Pers. Soc. Psychol.* 61, 708–720. doi: 10.1037/0022-3514.61.5.708
- Formann, A. K., and Pitswanger, K. (1979). *Wiener Matrizen-Test. Ein Rasch-skaliertes sprachfreier Intelligenztest [Viennese Matrices Test: A Rasch-scaled culture-fair intelligence test]*. Weinheim: Beltz.
- French, S., Epstein, L., and Jeffery, R. (2012). Eating behavior dimensions. Associations with energy intake and body weight. A review. *Appetite* 59, 541–549. doi: 10.1016/j.appet.2012.07.001
- García-García, I., Horstmann, A., Jurado, M. A., Garolera, M., Chaudhry, S. J., Margulies, D. S., et al. (2014). Reward processing in obesity, substance addiction and non-substance addiction. *Obes. Rev.* 15, 853–869. doi: 10.1111/obr.12221
- Gearhardt, A. N., Corbin, W. R., and Brownell, K. D. (2009). Preliminary validation of the Yale Food Addiction Scale. *Appetite* 52, 430–436. doi: 10.1016/j.appet.2008.12.003
- Green, L., Myerson, J., Lichtman, D., Rosen, S., and Fry, A. (1996). Temporal discounting in choice between delayed rewards: the role of age and income. *Psychol. Aging* 11, 79–84. doi: 10.1037/0882-7974.11.1.79
- Green, L., Myerson, J., and Ostaszewski, P. (1999). Amount of reward has opposite effects on the discounting of delayed and probabilistic outcomes. *J. Exp. Psychol. Learn. Mem. Cogn.* 25, 418–427. doi: 10.1037/0278-7393.25.2.418
- Guitart-Masip, M., Talmi, D., and Dolan, R. (2010). Conditioned associations and economic decision biases. *Neuroimage* 53, 206–214. doi: 10.1016/j.neuroimage.2010.06.021
- Guo, J., Simmons, W. K., Herscovitch, P., Martin, A., and Hall, K. D. (2014). Striatal dopamine D2-like receptor correlation patterns with human obesity and opportunistic eating behavior. *Mol. Psychiatry* 19, 1078–1084. doi: 10.1038/mp.2014.102
- Hall, P. A., Fong, G. T., and Epp, L. J. (2013). Cognitive and personality factors in the prediction of health behaviors: an examination of total, direct and indirect effects. *J. Behav. Med.* 24, 1918–1927. doi: 10.1007/s10865-013-9535-4
- Han, R., and Takahashi, T. (2012). Psychophysics of time perception and valuation in temporal discounting of gain and loss. *Phys. A Stat. Mech. Appl.* 391, 6568–6576. doi: 10.1016/j.physa.2012.07.012
- Hays, N. P., and Roberts, S. B. (2008). Aspects of eating behaviors “disinhibition” and “restraint” are related to weight gain and BMI in women. *Obesity (Silver Spring)* 16, 52–58. doi: 10.1038/oby.2007.12
- Hill, J. O., and Peters, J. C. (1998). Environmental contributions to the obesity epidemic. *Science* 280, 1371–1374. doi: 10.1126/science.280.5368.1371
- Hinest, N. S., and Anderson, I. M. (2010). The effects of real versus hypothetical reward on delay and probability discounting. *Q. J. Exp. Psychol. (Hove)* 63, 1072–1084. doi: 10.1080/17470210903276350
- Hoebel, B. G., Avena, N. M., and Rada, P. (2007). Accumbens dopamine-acetylcholine balance in approach and avoidance. *Curr. Opin. Pharmacol.* 7, 617–627. doi: 10.1016/j.coph.2007.10.014
- Horstmann, A., Busse, F. P., Mathar, D., Müller, K., Lepsien, J., Schlögl, H., et al. (2011). Obesity-related differences between women and men in brain structure and goal-directed behavior. *Front. Hum. Neurosci.* 5:58. doi: 10.3389/fnhum.2011.00058
- Horstmann, A., Dietrich, A., Mathar, D., Pössel, M., Villringer, A., and Neumann, J. (2015a). Slave to habit? Obesity is associated with decreased behavioural sensitivity to reward devaluation. *Appetite* 87, 175–183. doi: 10.1016/j.appet.2014.12.212
- Horstmann, A., Fenske, W. K., and Hankir, M. K. (2015b). Argument for a non-linear relationship between severity of human obesity and dopaminergic tone. *Obes. Rev.* 16, 1–10. doi: 10.1111/obr.12303
- Jeffery, R., and Utter, J. (2003). The changing environment and population obesity in the United States. *Obes. Res.* 11, 12S–22S. doi: 10.1038/oby.2003.221
- Johnson, M. W., and Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *J. Exp. Anal. Behav.* 77, 129–146. doi: 10.1901/jeab.2002.77-129
- Kable, J. W., and Glimcher, P. W. (2007). The neural correlates of subjective value during intertemporal choice. *Nat. Neurosci.* 10, 1625–1633. doi: 10.1038/nn2007
- Kable, J. W., and Glimcher, P. W. (2010). An “as soon as possible” effect in human intertemporal decision making: behavioral evidence and neural mechanisms. *J. Neurophysiol.* 103, 2513–2531. doi: 10.1152/jn.00177.2009
- Kamijo, K., Khan, N. A., Pontifex, M. B., Scudder, M. R., Drollette, E. S., Raine, L. B., et al. (2012). The relation of adiposity to cognitive control and scholastic achievement in preadolescent children. *Obesity (Silver Spring)* 20, 2406–2411. doi: 10.1038/oby.2012.112
- Kim, B. K., and Zauberman, G. (2013). Can Victoria's Secret change the future? A subjective time perception account of sexual-cue effects on impatience. *J. Exp. Psychol. Gen.* 142, 328–335. doi: 10.1037/a0028954
- Kobayashi, S., and Schultz, W. (2014). Reward contexts extend dopamine signals to unrewarded stimuli. *Curr. Biol.* 24, 56–62. doi: 10.1016/j.cub.2013.10.061
- Koritzky, G., Yechiam, E., Bukay, I., and Milman, U. (2012). Obesity and risk taking. A male phenomenon. *Appetite* 59, 289–297. doi: 10.1016/j.appet.2012.05.020
- Labouëbe, G., Liu, S., Dias, C., Zou, H., Wong, J. C. Y., Karunakaran, S., et al. (2013). Insulin induces long-term depression of ventral tegmental area dopamine neurons via endocannabinoids. *Nat. Neurosci.* 16, 300–308. doi: 10.1038/nn.3321
- Laibson, D. (1997). Golden eggs and hyperbolic discounting. *Q. J. Econ.* 112, 443–477. doi: 10.1162/003355397555253
- Lang, P. J., Bradley, M. M., and Cuthbert, B. N. (1997). *International Affective Picture System (IAPS): Technical Manual and Affective Ratings*. NIMH Center for the Study of Emotion and Attention.
- Lang, P. J., Bradley, M. M., and Cuthbert, B. N. (2008). *International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual (Rep. No. A-8)*. Gainesville, FL: University of Florida.
- Larsen, H., Engels, R. C. M. E., Wiers, R. W., Granic, I., and Spijkerman, R. (2012). Implicit and explicit alcohol cognitions and observed alcohol consumption: three studies in (semi)naturalistic drinking settings. *Addiction* 107, 1420–1428. doi: 10.1111/j.1360-0443.2012.03805.x
- Laurent, V., Morse, A. K., and Balleine, B. W. (2014). The role of opioid processes in reward and decision-making. *Br. J. Pharmacol.* 14, 1–30. doi: 10.1111/bph.12818
- Leung, C. W., Laraia, B. A., Kelly, M., Nickleach, D., Adler, N. E., Kushi, L. H., et al. (2011). The influence of neighborhood food stores on change in young girls' body mass index. *Am. J. Prev. Med.* 41, 43–51. doi: 10.1016/j.amepre.2011.03.013



- Loewenstein, G., and Lerner, J. (2003). "The role of affect in decision making," in *Handbook of Affective Sciences*, eds R. Davidson, K. Scherer, and H. Goldsmith (Oxford: Oxford University Press), 619–642.
- Luo, S., Ainslie, G., and Monterosso, J. (2014). The behavioral and neural effect of emotional primes on intertemporal decisions. *Soc. Cogn. Affect. Neurosci.* 9, 283–291. doi: 10.1093/scan/nss132
- Madden, G. J., Begotka, A. M., Raiff, B. R., and Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Exp. Clin. Psychopharmacol.* 11, 139–145. doi: 10.1037/1064-1297.11.2.139
- Madden, G. J., Raiff, B. R., Lagorio, C. H., Begotka, A. M., Mueller, A. M., Hehli, D. J., et al. (2004). Delay discounting of potentially real and hypothetical rewards: II. Between- and within-subject comparisons. *Exp. Clin. Psychopharmacol.* 12, 251–261. doi: 10.1037/1064-1297.12.4.251
- Mazur, J. E. (1987). "An adjusting procedure for studying delayed reinforcement," in *Quantitative Analyses of Behavior: Vol. 5. The Effects of Delay and of Intervening Events on Reinforcement Value*, eds M. L. Commons, J. E. Mazur, J. A. Nevin, and H. Rachlin (Hillsdale, NJ: Erlbaum), 55–73.
- McClure, S. M., and Bickel, W. K. (2014). A dual-systems perspective on addiction: contributions from neuroimaging and cognitive training. *Ann. N.Y. Acad. Sci.* 1327, 62–78. doi: 10.1111/nyas.12561
- McCrory, M. A., Fuss, P. J., McCallum, J. E., Yao, M., Vinken, A. G., Hays, N. P., et al. (1999). Dietary variety within food groups: association with energy intake and body fatness in men and women. *Am. J. Clin. Nutr.* 69, 440–447.
- Meule, A., Vögele, C., and Kübler, A. (2011). Psychometrische Evaluation der deutschen Barratt Impulsiveness Scale – Kurzversion (BIS-15). *Diagnostica* 57, 126–133. doi: 10.1026/0012-1924/a000042
- Mitchell, S., and Wilson, V. (2010). The subjective value of delayed and probabilistic outcomes: outcome size matters for gains but not for losses. *Behav. Process.* 83, 1–11. doi: 10.1016/j.beproc.2009.09.003
- Monteiro, C. A., Levy, R. B., Claro, R. M., de Castro, I. R. R., and Cannon, G. (2011). Increasing consumption of ultra-processed foods and likely impact on human health: evidence from Brazil. *Public Health Nutr.* 14, 5–13. doi: 10.1017/S136898010003241
- Mueller, K., Anwender, A., Möller, H. E., Horstmann, A., Lepsien, J., Busse, F., et al. (2011). Sex-dependent influences of obesity on cerebral white matter investigated by diffusion-tensor imaging. *PLoS ONE* 6:e18544. doi: 10.1371/journal.pone.0018544
- Murawski, C., Harris, P. G., Bode, S., Domínguez, D., J. F., and Egan, G. F. (2012). Led into temptation? Rewarding brand logos bias the neural encoding of incidental economic decisions. *PLoS ONE* 7:e34155. doi: 10.1371/journal.pone.0034155
- Narayanawami, V., Thompson, A. C., Cassis, L. A., Bardo, M. T., and Dwoskin, L. P. (2013). Diet-induced obesity: dopamine transporter function, impulsivity and motivation. *Int. J. Obes. (Lond)*. 37, 1095–1103. doi: 10.1038/ijo.2012.178
- Nederkoorn, C., Smulders, F. T. Y., Havermans, R. C., Roefs, A., and Jansen, A. (2006). Impulsivity in obese women. *Appetite* 47, 253–256. doi: 10.1016/j.appet.2006.05.008
- Nijis, I. M. T., Muris, P., Euser, A. S., and Franken, I. H. A. (2010). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite* 54, 243–254. doi: 10.1016/j.appet.2009.11.004
- Nummenmaa, L., Hirvonen, J., Hannukainen, J. C., Immonen, H., Lindroos, M. M., Salminen, P., et al. (2012). Dorsal striatum and its limbic connectivity mediate abnormal anticipatory reward processing in obesity. *PLoS ONE* 7:e31089. doi: 10.1371/journal.pone.0031089
- Patton, J. H., Stanford, M. S., and Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *J. Clin. Psychol.* 51, 768–774.
- Peters, J., and Büchel, C. (2010). Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-midtemporal interactions. *Neuron* 66, 138–148. doi: 10.1016/j.neuron.2010.03.026
- Pignatti, R., Bertella, L., and Albani, G. (2006). Decision-making in obesity: a study using the Gambling Task. *Eat. Weight* 11, 126–132. doi: 10.1007/BF03327557
- Puhl, R. M., and Heuer, C. A. (2009). The stigma of obesity: a review and update. *Obesity (Silver Spring)*. 17, 941–964. doi: 10.1038/oby.2008.636
- Rippe, J. M., and McInnis, K. J. (2001). Physician involvement in the management of obesity as a primary medical condition. *Obes. Res.* 9, 302S–311S. doi: 10.1038/oby.2001.135
- Roefs, A., Huijding, J., Smulders, F. T. Y., MacLeod, C. M., de Jong, P. J., Wiers, R. W., et al. (2011). Implicit measures of association in psychopathology research. *Psychol. Bull.* 137, 149–193. doi: 10.1037/a0021729
- Roefs, A., and Jansen, A. (2002). Implicit and explicit attitudes toward high-fat foods in obesity. *J. Abnorm. Psychol.* 111, 517–521. doi: 10.1037/0021-843X.111.3.517
- Rothmund, Y., Preuschhof, C., Böhner, G., Bauknecht, H.-C., Klingebiel, R., Flor, H., et al. (2007). Differential activation of the dorsal striatum by high-calorie visual food stimuli in obese individuals. *Neuroimage* 37, 410–421. doi: 10.1016/j.neuroimage.2007.05.008
- Samuelson, P. (1937). A note on the measurement of utility. *Rev. Econ. Stud.* 4, 155–161. doi: 10.2307/2967612
- Sanchez-Roige, S., Ripley, T. L., and Stephens, D. N. (2014). Alleviating waiting impulsivity and perseverative responding by  $\mu$ -opioid receptor antagonism in two inbred mouse strains. *Psychopharmacology (Berl)*. 232, 1483–1492. doi: 10.1007/s00213-014-3786-9
- Scott, C., and Johnstone, A. M. (2012). Stress and eating behaviour: implications for obesity. *Obes. Facts* 5, 277–287. doi: 10.1159/000338340
- Shamosh, N. A., Deyoung, C. G., Green, A. E., Reis, D. L., Johnson, M. R., Conway, A. R., et al. (2008). Individual differences in delay discounting: relation to intelligence, working memory, and anterior prefrontal cortex. *Psychol. Sci.* 19, 904–911. doi: 10.1111/j.1467-9280.2008.02175.x
- Shamosh, N. A., and Gray, J. R. (2008). Delay discounting and intelligence: a meta-analysis. *Intelligence* 36, 289–305. doi: 10.1016/j.intell.2007.09.004
- Sharma, S., and Fulton, S. (2013). Diet-induced obesity promotes depressive-like behaviour that is associated with neural adaptations in brain reward circuitry. *Int. J. Obes. (Lond)*. 37, 382–389. doi: 10.1038/ijo.2012.48
- Sheets, V., and Ajmere, K. (2005). Are romantic partners a source of college students' weight concern? *Eat. Behav.* 6, 1–9. doi: 10.1016/j.eatbeh.2004.08.008
- Stoeckel, L. E., Weller, R. E., Cook, E. W. III, Twieg, D. B., Knowlton, R. C., and Cox, J. E. (2008). Widespread reward-system activation in obese women in response to pictures of high-calorie foods. *Neuroimage* 41, 636–647. doi: 10.1016/j.neuroimage.2008.02.031
- St-Onge, M. P., Keller, K. L., and Heymsfield, S. B. (2003). Changes in childhood food consumption patterns: a cause for concern in light of increasing body weights. *Am. J. Clin. Nutr.* 78, 1068–1073.
- Strahan, E. J., Spencer, S. J., and Zanna, M. P. (2002). Subliminal priming and persuasion: striking while the iron is hot. *J. Exp. Soc. Psychol.* 38, 556–568. doi: 10.1016/S0022-1031(02)00502-4
- Stunkard, A. J., and Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J. Psychosom. Res.* 29, 71–83. doi: 10.1016/0022-3999(85)90010-8
- Takahashi, T. (2005). Loss of self-control in intertemporal choice may be attributable to logarithmic time-perception. *Med. Hypotheses* 65, 691–693. doi: 10.1016/j.mehy.2005.04.040
- Thaler, R. H. (1981). Some empirical evidence on dynamic inconsistency. *Econ. Lett.* 8, 201–207. doi: 10.1016/0165-1765(81)90067-7
- Treadway, M. T., Buckholtz, J. W., Cowan, R. L., Woodward, N. D., Li, R., Ansari, M. S., et al. (2012). Dopaminergic mechanisms of individual differences in human effort-based decision-making. *J. Neurosci.* 32, 6170–6176. doi: 10.1523/JNEUROSCI.6459-11.2012
- Tulving, E., and Schacter, D. L. (1990). Priming and human memory systems. *Science* 247, 301–306. doi: 10.1126/science.2296719
- Tusche, A., Bode, S., and Haynes, J.-D. (2010). Neural responses to unattended products predict later consumer choices. *J. Neurosci.* 30, 8024–8031. doi: 10.1523/JNEUROSCI.0064-10.2010
- Van den Bergh, B., Dewitte, S., and Warlop, L. (2008). Bikinis instigate generalized impatience in intertemporal choice. *J. Consum. Res.* 35, 85–97. doi: 10.1086/525505
- Van der Wal, A. J., Schade, H. M., Krabbendam, L., and van Vugt, M. (2013). Do natural landscapes reduce future discounting in humans? *Proc. Biol. Sci.* 280:20132295. doi: 10.1098/rspb.2013.2295
- Wang, G. J., Volkow, N. D., Logan, J., Pappas, N. R., Wong, C. T., Zhu, W., et al. (2001). Brain dopamine and obesity. *Lancet* 357, 354–357. doi: 10.1016/S0140-6736(00)03643-6
- Wang, G.-J., Volkow, N. D., Telang, F., Jayne, M., Ma, Y., Pradhan, K., et al. (2009). Evidence of gender differences in the ability to inhibit brain activation

- elicited by food stimulation. *Proc. Natl. Acad. Sci. U.S.A.* 106, 1249–1254. doi: 10.1073/pnas.0807423106
- Wassum, K. M., and Izquierdo, A. (2015). The basolateral amygdala in reward learning and addiction. *Neurosci. Biobehav. Rev.* doi: 10.1016/j.neubiorev.2015.08.017. [Epub ahead of print].
- Watkins, B. A., and Kim, J. (2015). The endocannabinoid system: directing eating behavior and macronutrient metabolism. *Front. Psychol.* 5:1506. doi: 10.3389/fpsyg.2014.01506
- Weller, R. E., Cook, E. W. III., Avsar, K. B., and Cox, J. E. (2008). Obese women show greater delay discounting than healthy-weight women. *Appetite* 51, 563–569. doi: 10.1016/j.appet.2008.04.010
- Whiteside, S. P., and Lynam, D. R. (2001). The five factor model and impulsivity: using a structural model of personality to understand impulsivity. *Pers. Individ. Dif.* 30, 669–689. doi: 10.1016/S0191-8869(00)00064-7
- Wiers, R. W., Van Woerden, N., Smulders, F. T. Y., and de Jong, P. J. (2002). Implicit and explicit alcohol-related cognitions in heavy and light drinkers. *J. Abnorm. Psychol.* 111, 648–658. doi: 10.1037/0021-843X.111.4.648
- Wittmann, M., and Paulus, M. P. (2008). Decision making, impulsivity and time perception. *Trends Cogn. Sci.* 12, 7–12. doi: 10.1016/j.tics.2007.10.004
- Zauberman, G. A. L., Kim, B. K. Y. U., Malkoc, S. A., and Bettman, J. R. (2009). Discounting time and time discounting: subjective time perception and intertemporal preferences. *J. Mark. Res.* 46, 543–556. doi: 10.1509/jmkr.46.4.543

**Conflict of Interest Statement:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## **Zusammenfassung**

Dissertation zur Erlangung des akademischen Grades Dr. med.

### **Titel:**

Biasing reward-based decision-making in obesity

### **eingereicht von:**

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Leipzig, Oktober 2016

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## **3. Summary**

### **3.1 Introduction and research questions**

Obesity rates have increased dramatically over the course of the last few decades. Alongside important genetic and metabolic aberrations (e.g. Rahilly et al. 2006; Choquet & Meyre 2011; Alfredo Martínez et al. 2007; Pi-Sunyer 2002), recent research into the etiology of obesity has focused on cognitive and behavioral mechanisms which might underlie weight gain and excess body weight (French et al. 2012; Dietrich et al. 2014; Horstmann et al. 2015; Jansen et al. 2015; Fitzpatrick et al. 2013).

One such mechanism is hypothesized to be impulsive decision-making.<sup>5</sup> Impulsive decision-making is, among other things, characterized by the inability to delay an

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<sup>5</sup> Note however that under certain circumstances impulsivity might be beneficial, or ‘functional’, as Dickman (1990) proposed.

immediate reward in order to receive a larger reward at a given time point in the future. This inability to delay gratification can be measured by the so-called delay discounting (DD), a paradigm of inter-temporal choice. DD assesses the decline of the subjective value of a delayed reward over time.

While an overreliance on immediate gratification in the food-context has been shown to be linked to obesity, it is not clear yet whether this applies to decisions in other contexts as well. A domain-general overreliance on immediate gratification would have serious implications given that it has been directly linked to a diverse set of negative outcomes. Impulsive individuals - who typically show a steep decline of subjective value over time - exhibit, among other things, less educational success and a higher risk of drug abuse (Casey et al. 2011; Mischel et al. 2011).

Thus, the first aim of this thesis was to clarify if obese subjects exhibit increased temporal impulsivity in other domains of decision-making, e.g. economic decisions. In addition, previous research consistently suggested that obese subjects' dietary decisions are susceptible to the decision-making context, i.e. to incidental external cues or emotional states present at the time of decision (Hays & Roberts 2008; Bryant et al. 2008; Scott & Johnstone 2012; Carnell & Wardle 2007; Carnell & Wardle 2008). However, little is known about the stability of obese subjects' decision-making preferences in other domains. Hence, this thesis' second aim was to test if obese and lean subjects differed in the degree of stability of financial inter-temporal decision-making preferences, when presented with incidental rewarding cues aiming at biasing their choices.

### **3.2 Methods**

52 healthy participants (26 male, 26 female, 26 lean: BMI: 18.5 – 25 kg/m<sup>2</sup>, 26 obese: BMI: 30 – 40 kg/m<sup>2</sup>) aged 18-35 completed two computerized DD task sessions. To control for factors that potentially affect delay discounting task performance I matched participants for general intelligence, education level and household income. Further, subjects completed several self-report questionnaires which assessed impulsivity as well as sensitivity to reward/punishment, subjective time perception and eating behavior.

In the first session, called Baseline session, participants were presented with a set of sooner smaller (SS) and larger later (LL) rewards and had to decide according to their individual preferences. A titration task produced parameter estimates for the participants' intertemporal preferences which were validated in the second part of the task. To determine the shape of the discount function the fit of three different discount functions (Exponential: Samuelson 1937; Hyperbolic: Mazur 1987; Quasi-hyperbolic: Laibson 1997;) modeled to the participants' choices was compared. I used a maximum likelihood estimation to estimate the discount models' parameters

and calculated the Bayesian Information Criterion (BIC), an index for the goodness of fit. The analysis of the Baseline session was based on a comparison of the models' discount parameters between weight status and gender groups.

In the second session, called Priming session, participants were presented with rewarding pictures of different context categories (erotic, food and social) before each decision. The cues utilized were taken from the International Affective Picture System and had been rated for perceived valence and arousal by an independent sample of 44 participants with demographics comparable to the study sample. The analysis of the Priming session was based on comparing the inter-temporal choice preferences between the unprimed and the primed trials in order to reveal the participants' susceptibility towards incidental rewarding cues. Several repeated-measure ANOVAs were performed to test for main effects and interactions between the subgroups of the sample.

### **3.3 Results and discussion**

Of the three discount functions applied to the participants' choices the quasi-hyperbolic model (Laibson 1997) exhibited the best fit (lowest mean BIC of the likelihood model). Consequently, its parameters were used for all following analyses. A two-way analysis of variance of the discounting parameter  $\delta$ , which describes the decline of the subjective reward of the delayed choice option as a function of the time until receipt, revealed a significant main effect for weight status group [ $F(1,51) = 5.02$ ;  $p = 0.03$ ]: Obese participants decided more impulsively in a DD task using monetary reinforcers. Hence, this thesis supports the notion that obesity might be characterized by behavioral impulsivity that is domain-general in nature and not restricted to the dietary context. This is in line with recent findings describing abnormalities in brain structure and function as well as dopaminergic signaling present in obese. In specific, structural differences in the ventral striatum and the OFC might account for differences in domain-general subjective reward value computation between lean and obese; while a compromised function of the dopaminergic system, including dopamine D2-receptor availability, altered dopaminergic tone and inefficacy of the dopamine transporter, is likely to heavily alter reward seeking behavior.

Further, I tested for a direct relation between the degree of temporal impulsivity and self-reported eating behavior. I found that the degree of temporal impulsivity exhibited by obese subjects was directly correlated to their tendency towards 'opportunistic eating' [Spearman's  $\rho$  (obese) =  $-0.46$ ,  $p = 0.03$ ; Spearman's  $\rho$  (lean) =  $0.06$ ,  $p = 0.79$ ; two-tailed] suggesting that there is a certain overlap of temporal impulsivity and eating behavior. 'Opportunistic eating' (or disinhibition) is one of the three dimensions of the Three-Factor Eating Questionnaire (Stunkard & Messick

1985; German: Fragebogen zum Essverhalten (FEV), Pudel & Westenhöfer 1989) and has been shown to predict weight gain and BMI (Bryant et al. 2008; Hays & Roberts 2008; Hays et al. 2002; French et al. 2012). It is characterized by a tendency to lose control over one's eating behavior, especially when confronted with environmental temptations, but also when emotionally moved or under stress. As such it defines an increased susceptibility of eating behavior towards internal states and external cues.

Finally, I tested for the stability of inter-temporal decision-making preferences with regard to changes of context. Several repeated-measures ANOVAs were used to test for a priming effect in the Priming task. The analysis revealed no main effect for gender or weight status groups [ $F_{\text{food}}(1, 47) = 0.15, p = 0.7$ ;  $F_{\text{social}}(1, 47) = 0.02, p = 0.88$ ;  $F_{\text{erotic}}(1, 48) = 3.24, p = 0.08$ ]. However, it revealed a gender x obesity interaction for the food and social picture category [ $F_{\text{food}}(1, 44) = 4.21, p = 0.04$ ;  $F_{\text{social}}(1, 44) = 4.24, p = 0.04$ ]: Obese women's choices, after being primed by social and food cues, tended to be more future-oriented while obese men's choices were more present-oriented. To the contrary, lean subjects' choices were not primed by the presented stimuli. Thus, these results provide evidence for an increased susceptibility of economic decision-making towards external cues in obese subjects. Interestingly, the direction of the priming effect was gender-specific.

Recently, a study investigating priming by emotional cues in the general population was the first to find such a bi-directionality of priming (Luo et al. 2014). Priming with negative cues, i.e. fearful faces, led to more future-oriented choices while priming with happy faces induced a stronger present-orientation. The priming effect towards more present-oriented choices was in line with preceding research. The priming effect towards more future-oriented choices in contrast might be explained by a so-called inhibition spillover effect (Berkman et al. 2009) relying on the hypothesis that there is a common inhibitory mechanism across multiple psychological domains and that inhibition in one domain is likely to simultaneously induce inhibition in other domains. In the context of this study, induced emotional inhibition, as a reaction to the presentation of sad faces, might unintentionally have led to behavioral inhibition thereby causing subjects to restrain from seeking immediate gratification.

Applied to the gender-specificity of the priming effect in obese subjects the theory of 'inhibition spillover' suggests that the presented stimuli, namely food pictures and pictures of happy social scenes, were differently perceived by obese men and women. In fact, it indicates that obese women perceived the cues as negative while obese men perceived them as positive and rewarding. While a differential perception was not mirrored in the explicit valence ratings of the pictures, an implicit negative evaluation by obese women is likely and would be in accordance with recent

research. (food cues: Roefs & Jansen 2002; Cornier et al. 2010; social cues: Puhl & Heuer 2009; Sheets & Ajmone 2005; Chen & Brown 2005).

### **3.4 Implications**

This thesis provides evidence that obesity has a strong cognitive component. It is accompanied by increased temporal impulsivity and an increased susceptibility of decision-making preferences towards external cues. Importantly, these behavioral aberrations are not restricted to the food context and cannot be explained by differences in IQ, age, socioeconomic status and other confounding variables.

This implies that the treatment of obesity should not be based on medical means only, but should include training of executive functioning (Hall et al. 2013; McClure & Bickel 2014), impulse control and working memory (Shamosh et al. 2008; Shamosh & Gray 2008; Bickel et al. 2011). In this way, temporal impulsivity might be weakened leading to an increased adherence to dietary goals and life-style changes. Such an approach, however, is likely to act well beyond dietary and body weight control. Recent research showed how strongly correlated inter-temporal decisions in different domains (e.g. health-related and financial decision, see Gubler and Pierce 2014) are. Changing inter-temporal preferences towards a stronger future-orientation might thus have positive effects for decisions in many other spheres of life.

The fact that possible psychological treatment options weakening temporal impulsivity exist, however, does not mean that pharmacological treatment options should generally be discarded. To the contrary, we actually experience a lack of pharmacological treatment options for obesity. Even though it did not directly investigate dopaminergic,  $\mu$ -opioid and endocannabinoid receptor systems, this thesis suggests that pharmacologically intervening with these systems might reduce temporal impulsivity and normalize detrimental eating behavior patterns at the same time (Horstmann et al. 2015; Cambridge et al. 2013; Laurent et al. 2014; Sanchez-Roige et al. 2014; Boomhower et al. 2013; Boomhower & Rasmussen 2014; Watkins & Kim 2015).

Additionally, this yields that obese people's decision-making preferences might be more susceptible to environmental cues. Future public health strategies might thus be well advised to shield obese people's decisions from environmental cues inducing immediate reward seeking – inside (see e.g. Mozaffarian et al. 2014; Yasare 2006; Weiss & Smith 2004) and outside the food context.

#### 4. Bibliography of introduction and summary (for the publication's bibliography, see pp. 28-31)

- Ainslie, G., 1975. Specious reward: a behavioral theory of impulsiveness and impulse control. *Psychological bulletin*, 82(4), pp.463–496. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19586159>.
- Alessi, S., & Petry, N., 2003. Pathological gambling severity is associated with impulsivity in a delay discounting procedure. *Behavioural Processes*, 64(3), pp.345–354. Available at: <http://www.sciencedirect.com/science/article/pii/S0376635703001505>.
- Alfredo Martínez, J. et al., 2007. Genetics of obesity. *Public health nutrition*, 10(10A), pp.1138–44. Available at: [http://journals.cambridge.org/abstract\\_S1368980007000626](http://journals.cambridge.org/abstract_S1368980007000626).
- Bargh, J. a., 1990. Auto Motives. Preconscious Determinants of Social Interaction. In R. M. Sorrentino & E. T. Higgins, eds. *Handbook of Motivation and Cognition: Foundations of Social Behavior*. New York, NY, pp. 93–130.
- Batterink, L., Yokum, S. & Stice, E., 2010. Body mass correlates inversely with inhibitory control in response to food among adolescent girls: an fMRI study. *Neuroimage*, 52(4), pp.1696–1703. Available at: <http://www.sciencedirect.com/science/article/pii/S1053811910007925>.
- Begg, D.P. & Woods, S.C., 2013. Hedonic and homeostatic overlap following fat ingestion. *Cell Metabolism*, 18(4), pp.459–460. Available at: <http://dx.doi.org/10.1016/j.cmet.2013.09.012>.
- Berg, L. Van Den et al., 2011. Association between impulsivity , reward responsiveness and body mass index in children. *International Journal of Obesity*, 35(10), pp.1301–1307. Available at: <http://dx.doi.org/10.1038/ijo.2011.116>.
- Van den Bergh, B., Dewitte, S. & Warlop, L., 2008. Binkies Instigate Generalized Impatience in Intertemporal Choice. *Journal of Consumer Research*, 35(1), pp.85–97. Available at: <http://www.jstor.org/stable/10.1086/525505>.
- Berkman, E.T., Burkund, L. & Lieberman, M.D., 2009. Inhibitory spillover: intentional motor inhibition produces incidental limbic inhibition via right inferior frontal cortex. *NeuroImage*, 47(2), pp.705–12. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2700187&tool=pmcentrez&rendertype=abstract>.
- Bickel, W.K. et al., 2011. Remember the future: working memory training decreases delay discounting among stimulant addicts. *Biological psychiatry*, 69(3), pp.260–5. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3015021&tool=pmcentrez&rendertype=abstract>.
- Bijleveld, E., Custers, R. & Aarts, H., 2012. Adaptive reward pursuit: how effort requirements affect unconscious reward responses and conscious reward decisions. *Journal of experimental psychology. General*, 141(4), pp.728–42. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22468672>.
- Bjork, J.M. et al., 2004. Impulsivity in abstinent alcohol-dependent patients: Relation to control subjects and type 1-/type 2-like traits. *Alcohol*, 34(2–3), pp.133–150.
- Boomhower, S. & Rasmussen, E.B., 2014. Haloperidol and rimonabant increase delay discounting in rats fed high-fat and standard-chow diet. *Behavioural pharmacology*, 25(8), pp.705–16.
- Boomhower, S.R., Rasmussen, E.B. & Doherty, T.S., 2013. Impulsive-choice patterns for food in genetically lean and obese Zucker rats. *Behavioral Brain Research*, 241, pp.214–221.
- Brogan, A., Hevey, D. & Pignatti, R., 2010. Anorexia, bulimia, and obesity: shared decision making deficits on the Iowa Gambling Task (IGT). *Journal of the international neuropsychological society*, 16(4), pp.711–5.
- Bryant, E.J., King, N. a & Blundell, J.E., 2008. Disinhibition: its effects on appetite and weight regulation. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, 9(5), pp.409–19. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18179615>.
- Cambridge, V.C. et al., 2013. Neural and behavioral effects of a novel Mu opioid receptor antagonist in binge-eating obese people. *Biological Psychiatry*, 73(9), pp.887–894. Available at: <http://dx.doi.org/10.1016/j.biopsych.2012.10.022>.
- Camchong, J. et al., 2011. Frontal Hyperconnectivity Related to Discounting and Reversal Learning in Cocaine Subjects. *Biological Psychiatry*, 69(11), pp.1117–1123.
- Carver, C.S. & White, T.L., 1994. Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, 67(2), pp.319–333. Available at: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.67.2.319>.
- Casey, B.J. et al., 2011. Behavioral and neural correlates of delay of gratification 40 years later. *Proceedings of the National Academy of Sciences of the United States of America*, 108(36), pp.14998–5003. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3169162&tool=pmcentrez&rendertype=abstract>.



- Chartrand, T.L. & Bargh, J. a., 1996. Automatic activation of impression formation and memorization goals: Nonconscious goal priming reproduces effects of explicit task instructions. *Journal of Personality and Social Psychology*, 71(3), pp.464–478. Available at: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.71.3.464>.
- Chen, E.Y. & Brown, M., 2005. Obesity stigma in sexual relationships. *Obesity research*, 13(8), pp.1393–7. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16129721>.
- Choquet, H. & Meyre, D., 2011. Genetics of Obesity: What have we Learned? *Current genomics*, 12(3), pp.169–79. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3137002&tool=pmcentrez&rendertype=abstract>.
- Cone, J.J. et al., 2013. Prolonged High Fat Diet Reduces Dopamine Reuptake without Altering DAT Gene Expression. *PLoS ONE*, 8(3), pp.1–10.
- Cooper, N. et al., 2013. Brain Activity in Valuation Regions while Thinking about the Future Predicts Individual Discount Rates. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 33(32), pp.13150–6. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23926268>.
- Coppin, G. et al., 2014. Working memory and reward association learning impairments in obesity. *Neuropsychologia*, 65, pp.146–55. Available at: <http://www.sciencedirect.com/science/article/pii/S0028393214003649>.
- Cornier, M., Salzberg, A. & Endly, D., 2010. Sex-based differences in the behavioral and neuronal responses to food. *Physiology & behavior*, 99(4), pp.538–543. Available at: <http://www.sciencedirect.com/science/article/pii/S0031938410000211>.
- Czyzewska, M. & Graham, R., 2008. Implicit and explicit attitudes to high- and low-calorie food in females with different BMI status. *Eating behaviors*, 9(3), pp.303–12. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18549989>.
- Daruna, J.H. & Barnes, P.A., 1993. A neurodevelopmental view of impulsivity. In W. McCown, J. Johnson, & M. Shure, eds. *The impulsive client: theory, research and treatment*. Washington, DC: American Psychological Association, pp. 23–37.
- Davis, C. et al., 2010. Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite*, 54(1), pp.208–13. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19896515>.
- Deyoung, C.G., 2011. Impulsivity as a Personality Trait. In K. D. Vohs & R. F. Baumeister, eds. *Handbook of self regulation*. New York, NY, pp. 485–502.
- Dietrich, A. et al., 2014. Body weight status, eating behavior, sensitivity to reward/punishment, and gender: relationships and interdependencies. *Frontiers in Psychology*, 5, pp.1–13. Available at: [http://www.frontiersin.org/Eating\\_Behavior/10.3389/fpsyg.2014.01073/abstract](http://www.frontiersin.org/Eating_Behavior/10.3389/fpsyg.2014.01073/abstract).
- Dixon, M.R., Marley, J. & Jacobs, E.A., 2003. Delay discounting by pathological gamblers. *Journal of applied behavior analysis*, 36(4), pp.449–458. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1284461&tool=pmcentrez&rendertype=abstract>.
- Dougherty, D.M. et al., 2009. Distinctions in Behavioral Impulsivity: Implications for Substance Abuse Research. *Addictive Disorders and Their Treatment*, 8(2), pp.61–73.
- Evenden, J.L., 1999a. Impulsivity: a discussion of clinical and experimental findings. *Journal of Psychopharmacology*, 13(2), pp.180–192. Available at: <http://jop.sagepub.com/cgi/doi/10.1177/026988119901300211>.
- Evenden, J.L., 1999b. Varieties of impulsivity. *Psychopharmacology*, 146(4), pp.348–61. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/10550486>.
- Eysenck, S.B. & Eysenck, H.J., 1977. The place of impulsiveness in a dimensional system of personality description. *The British journal of social and clinical psychology*, 16(1), pp.57–68.
- Fields, S.A., Sabet, M. & Reynolds, B., 2013. Dimensions of impulsive behavior in obese, overweight, and healthy-weight adolescents. *Appetite*, 70, pp.60–66. Available at: <http://dx.doi.org/10.1016/j.appet.2013.06.089>.
- Finn, P.R. & Hall, J., 2004. Cognitive ability and risk for alcoholism: short-term memory capacity and intelligence moderate personality risk for alcohol problems. *Journal of abnormal psychology*, 113(4), pp.569–581.
- Fitzpatrick, S., Gilbert, S. & Serpell, L., 2013. Systematic review: Are overweight and obese individuals impaired on behavioural tasks of executive functioning? *Neuropsychology Review*, 23, pp.138–156.
- French, S., Epstein, L. & Jeffery, R., 2012. Eating behavior dimensions. Associations with energy intake and body weight. A review. *Appetite*, 59(2), pp.541–549. Available at: <http://www.sciencedirect.com/science/article/pii/S0195666312002243>.
- García-García, I. et al., 2014. Reward processing in obesity, substance addiction and non-substance addiction. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, 15(11), pp.853–69. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25263466>.

- Graziano, P.A., Calkins, S.D. & Keane, S.P., 2010. Toddler self-regulation skills predict risk for pediatric obesity. *International journal of obesity* (2005), 34(4), pp.633–41. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2854309&tool=pmcentrez&rendertype=abstract>.
- Green, L. et al., 1996. Temporal discounting in choice between delayed rewards: the role of age and income. *Psychology and aging*, 11(1), pp.79–84. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/8726373>.
- Greenwald, A.G., McGhee, D.E. & Schwartz, J.L., 1998. Measuring individual differences in implicit cognition: the implicit association test. *Journal of Personality and Social Psychology*, 74(6), p.1464.
- Gubler, T. & Pierce, L., 2014. Healthy, wealthy, and wise: retirement planning predicts employee health improvements. *Psychological science*, 25(9), pp.1822–30. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24973136>.
- Guitart-Masip, M., Talmi, D. & Dolan, R., 2010. Conditioned associations and economic decision biases. *Neuroimage*, 53, pp.206–214. Available at: <http://www.sciencedirect.com/science/article/pii/S1053811910008657>.
- Hall, P. a, Fong, G.T. & Epp, L.J., 2013. Cognitive and personality factors in the prediction of health behaviors: an examination of total, direct and indirect effects. *Journal of behavioral medicine*, 24, pp.1918–1927. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24072429>.
- Han, R. & Takahashi, T., 2012. Psychophysics of time perception and valuation in temporal discounting of gain and loss. *Physica A: Statistical Mechanics and its Applications*, 391(24), pp.6568–6576. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0378437112006747>.
- Hays, N.P. et al., 2002. Eating behavior correlates of adult weight gain and obesity in healthy women aged 55–65 y. *The American journal of clinical nutrition*, 75(3), pp.476–83. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11864852>.
- Hays, N.P. & Roberts, S.B., 2008. Aspects of eating behaviors “disinhibition” and “restraint” are related to weight gain and BMI in women. *Obesity*, 16(1), pp.52–8. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2713727&tool=pmcentrez&rendertype=abstract>.
- Hill, J.O. & Peters, J.C., 1998. Environmental contributions to the obesity epidemic. *Science*, 280(5368), pp.1371–1374. Available at: <http://www.sciencemag.org/cgi/doi/10.1126/science.280.5368.1371>.
- Hoebel, B.G., Avena, N.M. & Rada, P., 2007. Accumbens dopamine-acetylcholine balance in approach and avoidance. *Current opinion in pharmacology*, 7(6), pp.617–627.
- Horstmann, A. et al., 2011. Obesity-Related Differences between Women and Men in Brain Structure and Goal-Directed Behavior. *Frontiers in human neuroscience*, 5(June), p.58. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3114193&tool=pmcentrez&rendertype=abstract>.
- Horstmann, A. et al., 2015. Slave to habit? Obesity is associated with decreased behavioural sensitivity to reward devaluation. *Appetite*, 87(April), pp.175–183. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/25543077>.
- Horstmann, a, Fenske, W.K. & Hankir, M.K., 2015. Argument for a non-linear relationship between severity of human obesity and dopaminergic tone. *Obesity Reviews*, 16(10), pp.1–10.
- Houben, K., Nederkoorn, C. & Jansen, A., 2014. Eating on impulse: The relation between overweight and food-specific inhibitory control. *Obesity*, 22(5), pp.2013–2015.
- Jansen, A., Houben, K. & Roefs, A., 2015. A cognitive profile of obesity and its translation into new interventions. *Frontiers in Psychology*, 6(Nov), pp.1–9.
- Jasinska, A.J. et al., 2012. Impulsivity and inhibitory control deficits are associated with unhealthy eating in young adults. *Appetite*, 59(3), pp.738–47. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22885454>.
- Jeffery, R. & Utter, J., 2003. The changing environment and population obesity in the United States. *Obesity research*, 11(October), Suppl:12S–22S. Available at: <http://onlinelibrary.wiley.com/doi/10.1038/oby.2003.221/full>.
- Joshi, P.D. & Fast, N.J., 2013. Power and reduced temporal discounting. *Psychological science*, 24(4), pp.432–8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23404083>.
- Kable, J.W. & Glimcher, P.W., 2010. An “as soon as possible” effect in human intertemporal decision making: behavioral evidence and neural mechanisms. *Journal of neurophysiology*, 103(5), pp.2513–31. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2867580&tool=pmcentrez&rendertype=abstract>.
- Kable, J.W. & Glimcher, P.W., 2007. The neural correlates of subjective value during intertemporal choice. *Nature neuroscience*, 10(12), pp.1625–33. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2845395&tool=pmcentrez&rendertype=abstract>.
- Kamijo, K. et al., 2012. The relation of adiposity to cognitive control and scholastic achievement in

- preadolescent children. *Obesity*, 20(12), pp.2406–11. Available at:  
<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3414677&tool=pmcentrez&rendertype=abstract>.
- Kemps, E., Tiggemann, M. & Hollitt, S., 2014. Exposure to television food advertising primes food-related cognitions and triggers motivation to eat. *Psychology and Health*, 29(10), pp.1192–205. Available at:  
<http://www.ncbi.nlm.nih.gov/pubmed/24773418>.
- Kirby, K., Petry, N. & Bickel, W., 1999. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology. General*, 128(1), pp.78–87. Available at:  
<http://psycnet.apa.org/journals/xge/128/1/78/>.
- Kirby, K.N., 2009. One-year temporal stability of delay-discount rates. *Psychonomic bulletin & review*, 16(3), pp.457–62. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19451368>.
- Kirby, K.N. & Petry, N.M., 2003. Heroin and cocaine abusers have higher discount rates for delayed rewards than alcoholics or non-drug-using controls. *Addiction*, 99, pp.461–471.
- Kobayashi, S. & Schultz, W., 2014. Reward contexts extend dopamine signals to unrewarded stimuli. *Current Biology*, 24(1), pp.56–62. Available at: <http://dx.doi.org/10.1016/j.cub.2013.10.061>.
- Laibson, D., 1997. Golden Eggs and Hyperbolic Discounting. *The Quarterly Journal of Economics*, 112(2), pp.443–477. Available at: <http://www.jstor.org/stable/2951242>.
- Laurent, V., Morse, A.K. & Balleine, B.W., 2014. The role of opioid processes in reward and decision-making. *British journal of pharmacology*, 14, pp.1–30. Available at:  
<http://www.ncbi.nlm.nih.gov/pubmed/24930675>.
- Lawyer, S.R., Boomhower, S.R. & Rasmussen, E.B., 2015. Differential associations between obesity and behavioral measures of impulsivity. *Appetite*, 95, pp.375–382. Available at:  
<http://www.sciencedirect.com/science/article/pii/S0195666315003487>.
- Lehnert, T. et al., 2015. Health burden and costs of obesity and overweight in Germany: an update. *European Journal of Health Economics*, 16(9), pp.957–967.
- Leung, C.W. et al., 2011. The influence of neighborhood food stores on change in young girls' body mass index. *American journal of preventive medicine*, 41(1), pp.43–51. Available at:  
<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3115539&tool=pmcentrez&rendertype=abstract>.
- Logan, G.D. & Cowan, W.B., 1984. On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review*, 91(3), pp.295–327. Available at:  
<http://linkinghub.elsevier.com/retrieve/pii/S0740547206003862%5Cnhttp://content.apa.org/journals/rev/91/3/295>.
- Lowe, M.R. & Butryn, M.L., 2007. Hedonic hunger: A new dimension of appetite? *Physiology and Behavior*, 91(4), pp.432–439.
- Luman, M., Tripp, G. & Scheres, A., 2010. Identifying the neurobiology of altered reinforcement sensitivity in ADHD: A review and research agenda. *Neuroscience and Biobehavioral Reviews*, 34(5), pp.744–754. Available at: <http://dx.doi.org/10.1016/j.neubiorev.2009.11.021>.
- Luo, S. et al., 2012. Moderators of the association between brain activation and farsighted choice. *NeuroImage*, 59(2), pp.1469–77. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21856429>.
- Luo, S., Ainslie, G. & Monterosso, J., 2014. The behavioral and neural effect of emotional primes on intertemporal decisions. *Social cognitive and affective neuroscience*, 9(3), pp.283–91. Available at:  
<http://www.ncbi.nlm.nih.gov/pubmed/23160811>.
- Mather, A.A. et al., 2009. Associations of obesity with psychiatric disorders and suicidal behaviors in a nationally representative sample. *Journal of Psychosomatic Research*, 66(4), pp.277–285. Available at:  
<http://dx.doi.org/10.1016/j.jpsychores.2008.09.008>.
- Mazur, J.E., 1987. An Adjusting Procedure for Studying Delayed Reinforcement. In M. L. Commons et al., eds. *Quantitative analyses of behavior: Vol. 5. The effects of delay and of intervening events on reinforcement value*. Hillsdale, N.J.: Erlbaum, pp. 55–73.
- McClure, S.M. & Bickel, W.K., 2014. A dual-systems perspective on addiction: contributions from neuroimaging and cognitive training. *Annals of the New York Academy of Sciences*, 1327, pp.62–78. Available at: <http://doi.wiley.com/10.1111/nyas.12561>.
- Minas, R.K. et al., 2016. A prime a day keeps calories away: The effects of supraliminal priming on food consumption and the moderating role of gender and eating restraint. *Appetite*. Available at:  
<http://www.sciencedirect.com/science/article/pii/S0195666316301994>.
- Mischel, W. et al., 2011. “Willpower” over the life span: decomposing self-regulation. *Social cognitive and affective neuroscience*, 6(2), pp.252–6. Available at:  
<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3073393&tool=pmcentrez&rendertype=abstract>.
- Mischel, W., Ebbesen, E.B. & Zeiss, a R., 1972. Cognitive and attentional mechanisms in delay of gratification. *Journal of personality and social psychology*, 21(2), pp.204–218.

- Mobbs, O. et al., 2010. Obesity and the four facets of impulsivity. *Patient education and counseling*, 79(3), pp.372–7. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20399590>.
- Monterosso, J.R. et al., 2007. Frontoparietal cortical activity of methamphetamine-dependent and comparison subjects performing a delay discounting task. *Human Brain Mapping*, 28(5), pp.383–393.
- Mozaffarian, D., Rogoff, K.S. & Ludwig, D.S., 2014. The real cost of food: Can taxes and subsidies improve public health? *JAMA*, 312(9), pp.889–890. Available at: <http://dx.doi.org/10.1001/jama.2014.8232%5Cnhttp://jama.jamanetwork.com/data/Journals/JAMA/930710/jvp140091.pdf>.
- Mueller, K. et al., 2011. Sex-dependent influences of obesity on cerebral white matter investigated by diffusion-tensor imaging. *PloS one*, 6(4), p.e18544. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3073967&tool=pmcentrez&rendertype=abstract>.
- Murawski, C. et al., 2012. Led into temptation? Rewarding brand logos bias the neural encoding of incidental economic decisions. *PloS one*, 7(3), p.e34155. Available at: <http://dx.plos.org/10.1371/journal.pone.0034155>.
- Narayanaswami, V. et al., 2012. Diet-induced obesity: dopamine transporter function, impulsivity and motivation. *International journal of obesity*, 37(8), pp.1095–1103. Available at: <http://dx.doi.org/10.1038/ijo.2012.178>.
- NCD Risk Factor Collaboration, 2016. Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet*, 387(10026), pp.1377–1396. Available at: [http://dx.doi.org/10.1016/S0140-6736\(16\)30054-X](http://dx.doi.org/10.1016/S0140-6736(16)30054-X).
- Nederkoorn, C. et al., 2006. Impulsivity in obese women. *Appetite*, 47(2), pp.253–6. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16782231>.
- Nummenmaa, L. et al., 2012. Dorsal striatum and its limbic connectivity mediate abnormal anticipatory reward processing in obesity. *PloS one*, 7(2), p.e31089. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3272045&tool=pmcentrez&rendertype=abstract>.
- Papies, E.K. et al., 2014. Using health primes to reduce unhealthy snack purchases among overweight consumers in a grocery store. *International journal of obesity*, 38(4), pp.597–602. Available at: <http://dx.doi.org/10.1038/ijo.2013.136>.
- Patton, J.H., Stanford, M.S. & Barratt, E.S., 1995. Factor structure of the Barratt impulsiveness scale. *Journal of clinical psychology*, 51(6), pp.768–74. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14551853>.
- Peters, J. & Büchel, C., 2010a. Episodic future thinking reduces reward delay discounting through an enhancement of prefrontal-mediocortical interactions. *Neuron*, 66(1), pp.138–48. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20399735>.
- Peters, J. & Büchel, C., 2010b. Neural representations of subjective reward value. *Behavioural brain research*, 213(2), pp.135–41. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20420859>.
- Peters, J. & Büchel, C., 2011. The neural mechanisms of inter-temporal decision-making: understanding variability. *Trends in cognitive sciences*, 15(5), pp.227–39. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21497544>.
- Pi-Sunyer, F.X., 2002. The obesity epidemic: pathophysiology and consequences of obesity. *Obesity research*, 10 (Suppl 2), pp.97S–104S.
- Pignatti, R., Bertella, L. & Albani, G., 2006. Decision-making in obesity: a study using the Gambling Task. *Eating and Weight Disorders: EW*, 11(3), pp.126–132. Available at: <http://link.springer.com/article/10.1007/BF03327557>.
- Prospective Studies Collaboration, 2009. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *The Lancet*, 373(9669), pp.1083–1096. Available at: [http://dx.doi.org/10.1016/S0140-6736\(09\)60318-4](http://dx.doi.org/10.1016/S0140-6736(09)60318-4).
- Pudel, V. & Westenhöfer, J., 1989. *Fragebogen zum Essverhalten (FEV): Handanweisung*.
- Puder, J.J. & Munsch, S., 2010. Psychological correlates of childhood obesity. *International journal of obesity*, 34 (Suppl 2), pp.S37–S43. Available at: <http://dx.doi.org/10.1038/ijo.2010.238>.
- Puhl, R.M. & Heuer, C. a, 2009. The stigma of obesity: a review and update. *Obesity*, 17(5), pp.941–964. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19165161>.
- Rahilly, S.O., Farooqi, I.S. & O’Rahilly, S., 2006. Genetics of obesity. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 361(1471), pp.1095–105. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1642700&tool=pmcentrez&rendertype=abstract>.
- Read, D., Frederick, S. & Scholten, M., 2013. DRIFT: an analysis of outcome framing in intertemporal choice. *Journal of experimental psychology. Learning, memory, and cognition*, 39(2), pp.573–88. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22866891>.
- Rippe, J.M., McInnis, K.J. & Melanson, K.J., 2001. Physician involvement in the management of obesity as a

- primary medical condition. *Obesity research*, 9(November), pp.302S–311S.
- Robert Koch-institut, 2014. Übergewicht und Adipositas. *Faktenblatt zu GEDA 2012: Ergebnisse der Studie "Gesundheit in Deutschland aktuelle 2012"*. RKI, Berlin. , pp.1–4.
- Roefs, A. & Jansen, A., 2002. Implicit and explicit attitudes toward high-fat foods in obesity. *Journal of Abnormal Psychology*, 111(3), pp.517–521. Available at: <http://doi.apa.org/getdoi.cfm?doi=10.1037/0021-843X.111.3.517>.
- Rydén, a et al., 2003. Severe obesity and personality: a comparative controlled study of personality traits. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity*, 27(12), pp.1534–40. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14634686>.
- Samuelson, P., 1937. A Note On the Measurement of Utility. *Review of Economic Studies*, 4, pp.155–61.
- Sanchez-Roige, S., Ripley, T.L. & Stephens, D.N., 2014. Alleviating waiting impulsivity and perseverative responding by  $\mu$ -opioid receptor antagonism in two inbred mouse strains. *Psychopharmacology*, pp.1483–1492. Available at: <http://link.springer.com/10.1007/s00213-014-3786-9>.
- Selvin, E. et al., 2014. Trends in prevalence and control of diabetes in the United States, 1988-1994 and 1999-2010. *Annals of Internal Medicine*, 160(8), pp.517–525.
- Shamosh, N. a et al., 2008. Individual differences in delay discounting: relation to intelligence, working memory, and anterior prefrontal cortex. *Psychological science*, 19(9), pp.904–11. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18947356>.
- Shamosh, N. a. & Gray, J.R., 2008. Delay discounting and intelligence: A meta-analysis. *Intelligence*, 36(4), pp.289–305. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0160289607001092>.
- Sharma, S. & Fulton, S., 2013. Diet-induced obesity promotes depressive-like behaviour that is associated with neural adaptations in brain reward circuitry. *International Journal of Obesity*, 37(3), pp.382–389. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22508336>.
- Sheets, V. & Ajmere, K., 2005. Are romantic partners a source of college students' weight concern? *Eating behaviors*, 6(1), pp.1–9. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15567106>.
- Simon, G.E. et al., 2006. Association between obesity and psychiatric disorders in the US adult population. *Archives of General Psychiatry*, 63(7), pp.824–830.
- Stoeckel, L.E. et al., 2008. Widespread reward-system activation in obese women in response to pictures of high-calorie foods. *NeuroImage*, 41(2), pp.636–47. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/18413289>.
- Strahan, E.J., Spencer, S.J. & Zanna, M.P., 2002. Subliminal priming and persuasion: Striking while the iron is hot. *Journal of Experimental Social Psychology*, 38(6), pp.556–568. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0022103102005024>.
- Stunkard, A. & Messick, S., 1985. The Three-Factor Eating Questionnaire to Measure Dietary Restraint, Disinhibition and Hunger. *Journal of Psychosomatic Research*, 29(I), pp.71–83.
- Thamotharan, S. et al., 2013. The role of impulsivity in pediatric obesity and weight status: A meta-analytic review. *Clinical Psychology Review*, 33(2), pp.253–262. Available at: <http://dx.doi.org/10.1016/j.cpr.2012.12.001>.
- Treadway, M.T. et al., 2012. Dopaminergic mechanisms of individual differences in human effort-based decision-making. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 32(18), pp.6170–6. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3391699&tool=pmcentrez&rendertype=abstract>.
- Trope, Y. & Liberman, N., 2010. Construal-level theory of psychological distance. *Psychological review*, 117(2), pp.440–463. Available at: <http://psycnet.apa.org/journals/rev/117/2/440/>.
- Tulving, E. & Schacter, D.L., 1990. Priming and human memory systems. *Science*, 247(4940), pp.301–306. Available at: <http://www.sciencemag.org/content/247/4940/301.short>.
- Tversky, A. & Kahneman, D., 1986. Rational choice and the framing of decisions. *Journal of business*, 59(4), pp.S251-S278. Available at: <http://www.jstor.org/stable/2352759>.
- Tversky, a & Kahneman, D., 1981. The framing of decisions and the psychology of choice. *Science*, 211(4481), pp.453–8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/7455683>.
- Wassum, K.M. & Izquierdo, A., 2015. The basolateral amygdala in reward learning and addiction. *Neuroscience and Biobehavioral Reviews*, 57, pp.271–283. Available at: <http://dx.doi.org/10.1016/j.neubiorev.2015.08.017>.
- Watkins, B. a. & Kim, J., 2015. The endocannabinoid system: directing eating behavior and macronutrient metabolism. *Frontiers in Psychology*, 5(January), pp.1–10. Available at: <http://journal.frontiersin.org/article/10.3389/fpsyg.2014.01506/abstract>.
- Weiss, R.I. & Smith, J.A., 2004. Legislative Approaches to the Obesity Epidemic. *Journal of Public Health Policy*, 25(3), pp.379–390.
- Weller, R.E. et al., 2008. Obese women show greater delay discounting than healthy-weight women. *Appetite*,

- 51(3), pp.563–9. Available at: <http://www.sciencedirect.com/science/article/pii/S0195666308001475>.
- Whiteside, S.P. & Lynam, D.R., 2001. The Five Factor Model and impulsivity: using a structural model of personality to understand impulsivity. *Personality and Individual Differences*, 30(4), pp.669–689. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0191886900000647>.
- de Wit, H. et al., 2007. IQ and nonplanning impulsivity are independently associated with delay discounting in middle-aged adults. *Personality and Individual Differences*, 42(1), pp.111–121. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S019188690600256X>.
- World Health Organization (WHO), 2000. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organization technical report series*, 894, p.i–xii, 1–253. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11234459>.
- Wormser, D. et al., 2011. Separate and combined associations of body-mass index and abdominal adiposity with cardiovascular disease: Collaborative analysis of 58 prospective studies. *The Lancet*, 377(9771), pp.1085–1095. Available at: [http://dx.doi.org/10.1016/S0140-6736\(11\)60105-0](http://dx.doi.org/10.1016/S0140-6736(11)60105-0).
- Yasare, A.A., 2006. The effects of television food advertisement on children's food purchasing requests. *Pediatrics International*, 48(2), pp.138–145.
- Zauberman, G.A.L. et al., 2009. Discounting Time and Time Discounting : Subjective Time Perception and Intertemporal Preferences. *Journal of Marketing Research*, XLVI(August), pp.543–556.

## 5. Anlagen

Leipzig, 24.08.2016

### Spezifizierung des eigenen wissenschaftlichen Beitrags


Hiermit bestätigen wir, dass Jakob Simmank in den folgenden Bereichen einen wichtigen Beitrag zur Publikation des folgenden Fachartikels

Simmank, J., Murawski, C., Bode, S., & Horstmann, A. (2015). Incidental rewarding cues influence economic decisions in people with obesity. *Frontiers in Behavioral Neuroscience*, 9: 278. doi:10.3389/fnbeh.2015.00278.

geleistet hat:

- Erarbeitung der Rationale der Studie unter Berücksichtigung bereits existierender Literatur.
- Erarbeitung des Studiendesigns, inkl. der Zusammensetzung der Vergleichsgruppen sowie Ein- und Ausschlusskriterien, der Prüfung möglicher experimenteller Paradigmen und der Entwicklung eines neuen Paradigmas zur Prüfung der Beeinflussbarkeit von intertemporaler Entscheidungsfindung durch visuelle Umweltreize.
- Programmierung des experimentellen Paradigmas.
- Probandenrekrutierung aus der Datenbank des Max-Planck-Instituts für Kognitions- und Neurowissenschaften, 'matching' der Vergleichsgruppen.
- Datenerhebung mittels computergesteuerter tasks (Rating task, Baseline task, Priming task), Einweisung der Probanden.
- Datenanalyse, vornehmlich mittels IBM SPSS.
- Interpretation der Ergebnisse vor dem Hintergrund der aktuellen Studienlage.
- Verfassen des Manuskripts.
- Einarbeiten der peer-reviews.

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A. Horstmann

  
C. Murawski

  
S. Bode

## **Erklärung über die eigenständige Abfassung der Arbeit**

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und ohne unzulässige Hilfe oder Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Ich versichere, dass Dritte von mir weder unmittelbar noch mittelbar eine Vergütung oder geldwerte Leistungen für Arbeiten erhalten haben, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen, und dass die vorgelegte Arbeit weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde zum Zweck einer Promotion oder eines anderen Prüfungsverfahrens vorgelegt wurde. Alles aus anderen Quellen und von anderen Personen übernommene Material, das in der Arbeit verwendet wurde oder auf das direkt Bezug genommen wird, wurde als solches kenntlich gemacht. Insbesondere wurden alle Personen genannt, die direkt an der Entstehung der vorliegenden Arbeit beteiligt waren. Die aktuellen gesetzlichen Vorgaben in Bezug auf die Zulassung der klinischen Studien, die Bestimmungen des Tierschutzgesetzes, die Bestimmungen des Gentechnikgesetzes und die allgemeinen Datenschutzbestimmungen wurden eingehalten. Ich versichere, dass ich die Regelungen der Satzung der Universität Leipzig zur Sicherung guter wissenschaftlicher Praxis kenne und eingehalten habe.

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## Persönliche Daten

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## Ausbildung und wissenschaftliche Erfahrungen

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- **Auslandssemester** an der Queen's University Belfast [09/2012 – 2/2013]: Studium der kognitiven Psychologie und Ethik
- **Famulaturen:** in der Neurologie (Campus Benjamin Franklin, Charité Berlin), Interdisziplinären Notaufnahme (Mater Hospital, Belfast, Nordirland), Radiologie (Hospital Universitarii, Palma de Mallorca, Spanien), Spezialisierten Ambulaten Palliativversorgung (Palliativ-Notdienst, Leipzig)
- **Praktisches Jahr** [11/2015 – 9/2016]: Tertiär Chirurgie am Hospital Alemán der Universidad de Buenos Aires: 8 Wochen Herz- und Gefäßchirurgie, 8 Wochen Allgemein- und Viszeralchirurgie; Tertiär Innere Medizin an der Robert-Koch-Klinik Leipzig-Grünau: 8 Wochen Pneumologie, 8 Wochen Onkologie/Geriatrie; Wahlfach Neurologie am Klinikum Altenburger Land.

### Wissenschaftliche Laufbahn

[01/2009 – heute]

- Mentoring-Programm für exzellente Studierende der Universität Hamburg bei Prof. A.K. Engel; Forschungspraktikum im Bereich der Tiefenhirnstimulation bei Parkinson-Erkrankung bei Dr. C. Moll [01/2009 – 09/2010]
- **Experimentelle Doktorarbeit** am Max-Planck-Institut für Kognitions- und Neurowissenschaften zum Thema 'Beeinflussung belohnungsbasierten Entscheidungsverhalten bei Adipositas'; Doktorvater: Prof. A. Villringer, Betreuung: Dr. A. Horstmann [seit: 10/2012]
- Aufbau einer wissenschaftlichen Kooperation mit dem 'Decision Neuroscience Laboratory Melbourne'

### Stipendien

[01/2008 – heute]

- Stipendium der Hans-Böckler-Stiftung [10/2008 – heute]
- Doktorandenstipendium des IFB Adipositas-Erkrankungen [10/2012 – 05/2013]
- Promos-Stipendium des DAAD für das Tertiär Chirurgie am Hospital Alemán, Buenos Aires [11/2015-02/2016]

## Engagement und Sonstiges

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### Engagement

- Mitglied der bundesweiten StipendiatInnenvertretung der Hans-Böckler-Stiftung (12/2008 – 6/2010)

- Zusammenstellung und Herausgabe einer Publikation zur Geschichte und Ethik der Medizin ("Medizin und Nationalsozialismus") im Aufbau Verlag, basierend auf einer selbstorganisierten Seminarreihe für Stipendiaten der Hans-Böckler-Stiftung [Beginn: 12/2013; voraussichtlicher Erscheinungstermin: Ende 2016]

### **Journalistische Erfahrungen**

- Freie Mitarbeit bei der Frankfurter Allgemeinen Sonntagszeitung, Zeit.Online und Zeit Magazin Wissen [07/2014 – heute]

### **Sprachenkenntnisse**

- sehr gute Englischkenntnisse (C1/2), gute Spanischkenntnisse (B2/C1)

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Datum

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Unterschrift

## Publikationen

### Publikationen:

Simmank, J., Murawski, C., Bode, S., & Horstmann, A. (2015). Incidental rewarding cues influence economic decisions in people with obesity. *Frontiers in Behavioral Neuroscience*, 9: 278. doi:10.3389/fnbeh.2015.00278.

### Poster:

Simmank, J., Murawski C, Bode, S, Neumann, & J, Horstmann, A. (2013) Biasing reward-based decision making in obesity. *Annual meeting of the German obesity society (DAG) 2013*.

Morys, F, Simmank, J, & Horstmann, A. (2016) BMI mediates the relationship between temporal impulsivity and cognitive restraint in women. *Meeting of the Society for the Study of Ingestive Behavior (SSIB) 2016*.

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